Generalization and Extension of the Environmental Enrichment Hypothesis of the OFCI Model

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Content

Abstract

This dissertation wants to test and generalize the Environmental Enrichment Hypothesis of the Openness-Fluid-Crystallized-Intelligence model (OFCI model, (Ziegler, Danay, Heene, Asendorpf, & Bühner, 2012). The OFCI model describes how the personality trait openness and intelligence influence each other in their adult development. The environmental enrichment hypothesis of the OFCI model focuses on the influence of openness on intelligence development. It assumes that a higher degree of openness would have a positive effect on intelligence development. This is based on the idea that people with higher levels of openness put themselves in more situations that have learning potential and, by using their fluid intelligence, promote this and also crystalline intelligence (Investment Hypothesis). Since this hypothesis has so far only been tested for younger and older adults, the present study shows, on the basis of two studies, that the Environmental Enrichment Hypothesis is valid for the entire adult age. Furthermore, the underlying assumption of the manifestation of openness in intelligence-enhancing behavior is tested.

The first study in this paper considers the Environmental Enrichment Hypothesis in the extension represented here from a structural perspective and uses a cross-sectional design for this purpose. It is assumed that openness manifests itself in reading and arithmetic activities at work and in leisure time. Such activities would lead to people being confronted with new situations from which they could learn. According to Cattell's investment theory, their fluid intelligence would be used, which would also have a positive effect on crystalline intelligence. On the basis of a representative sample it could be

shown that (1) the Environmental Enrichment Hypothesis can be generalized over the entire adult age, (2) the positive influence of openness on intelligence can be manifested in a certain leisure and work behavior, and (3) there is no difference in which of the behaviors (arithmetic vs. reading at work vs. leisure) openness manifests itself.

The second study looks again at the extension of the Environmental Enrichment Hypothesis by reading in leisure and at work. In this study the influence of openness on these activities is focused and considered in a long term design. In addition to this general perspective, the effect is sought from a specific perspective. It is examined whether openness can also have a positive effect during a period of unemployment. For this purpose, the influence of openness is examined specifically for people who became unemployed during the period under consideration. Openness should buffer the negative effects of unemployment on reading. The general effect could, but the specific effect could not be supported in this way.

Finally, the work is dedicated to the integration of the results of both studies. The generalization of the Environmental Enrichment Hypothesis to the whole adult age and its extension via manifestation in reading activities is discussed and used to generate further research questions.

Zusammenfassung

Die vorliegende Dissertation widmet sich der Überprüfung und Generalisierung der Environmental Enrichment Hypothese des Openness-Fluid-Crystallized-Intelligence Model (OFCI Model, (Ziegler, Danay, Heene, Asendorpf, & Bühner, 2012). Das OFCI-Model beschreibt, wie das Persönlichkeitstrait Offenheit und die Intelligenz sich gegenseitig in ihren Entwicklungen im Erwachsenenalter beeinflussen. Die Environmental Enrichment Hypothese des OFCI-Models hat dabei den Einfluss von Offenheit auf die Intelligenzentwicklung im Blick. Sie geht davon aus, dass sich höhere Ausprägung von Offenheit positive auf die Intelligenzentwicklung auswirkt. Dahinter steht der Gedanke, dass Personen mit höherer Offenheit sich in mehr Situationen begeben, die Lernpotenzial bergen und durch den Einsatz ihrer fluiden Intelligenz diese und auch die kristalline Intelligenz gefördert wird (Investment-Hypothese). Da diese Hypothese bisher nur für das jüngere und das ältere Erwachsenenalter geprüft wurde, möchte die vorliegende Arbeit anhand von zwei Studien zeigen, dass die Environmental Enrichment Hypothese für das gesamte Erwachsenenalter gilt. Darüber hinaus wird die dahinterstehende Annahme über die Manifestation von Offenheit in intelligenzförderndes Verhalten geprüft werden.

Die erste Studie dieser Arbeit betrachtet die Environmental Enrichment Hypothese in der hier vertretenden Erweiterung aus struktureller Perspektive und nutzt dafür ein cross-sectional Design. Es wird angenommen, dass sich Offenheit in Lese- und Rechenaktivitäten auf der Arbeit und in der Freizeit

manifestiert. Solche Aktivitäten würden dazu führen, dass Personen mit neuen Situationen konfrontiert werden, aus denen sie lernen könnten. Demnach würde ihre fluide Intelligenz genutzt, welches sich im Sinne der Investmenttheorie nach Cattell auch positiv auf die kristalline Intelligenz auswirken würde. Anhand einer repräsentativen Stichprobe könnte gezeigt werden, dass (1) die Environmental Enrichment Hypothese für Erwachsene gilt, (2) der positive Einfluss von Offenheit auf die Intelligenz über die Manifestation in ein bestimmtes Freizeit- und Arbeitsverhalten erfolgen kann, und (3) es keinen Unterschied gibt, in welchem der Verhaltensweise (Rechnen vs. Lesen auf Arbeit vs. in der Freizeit) sich Offenheit manifestiert.

Die zweite Studie betrachtet nochmal die Erweiterung der Environmental Enrichment Hypothese durch Lesen in der Freizeit und auf der Arbeit. In dieser Studie wird der Einfluss von Offenheit auf diese Aktivitäten fokussiert und in einem Längstschnittdesign betrachtet. Neben dieser generellen Perspektive wird der Effekt aus einer speziellen trachtet. Es wird geprüft, ob Offenheit auch während einer Phase der Arbeitslosigkeit einen positiven Effekt haben kann. Dazu wird der Einfluss von Offenheit speziell für Personen betrachtet, die im Betrachtungszeitraum arbeitslos geworden sind. Offenheit soll die negativen Auswirkungen von Arbeitslosigkeit auf das Lesen abpuffern. Der generelle Effekt konnte, aber der spezielle Effekt konnte auf diese Weise nicht gestützt werden.

Zum Abschluss widmet sich die Arbeit mit der Integration der Ergebnisse beider Studien. Die Generalisierung der Environmental Enrichment Hypothese auf das gesamte Erwachsenenalter und die Erweiterung über die

Manifestation in Leseaktvitäten wird diskutiert und genutzt, um weitere Forschungsfragen zu generieren.

Introduction

In 2002 Raine, Reynolds, Venables, and Mednick published a study about the influence of personality at a very young age on cognitive development. They found a positive impact of the personality trait stimulation seeking and sociability on the development of cognitive abilities. Thus, more physical exploration independently from the mother, more verbalization and friendliness towards strangers, as well as more cooperative playing with other children at a very young age (3 years) is positively associated with higher intelligence at the age of 11. Raine et al. (2002, p. 669) explain their results with environmental enrichment, which means that young "children who physically explore their environment, engage socially with other children, and verbally interact with adults, create themselves an enriched, stimulating, varied, and challenging environment". That would in turn result in enhanced cognitive abilities and better school performance. Thus, they found a positive effect of the exploration of environment on cognitive development that they traced back to differences in personality. The effect was called *Environmental Enrichment Hypothesis*.

In 2012, Ziegler, Danay, Heene, Asendorpf, and Bühner proposed a model about the cognitive development of adults. This also included the Environmental Enrichment Hypothesis, but was adapted to adults. The Environmental Enrichment Hypothesis of the Openness-Fluid-Crystallized-Intelligence (OFCI) model says that the personality trait Openness would foster the cognitive development. It is assumed that more Openness would drive

people into situations that could provide learning opportunities and that would positively affect cognitive development.

This dissertation will give a more specific look into the Environmental Enrichment Hypothesis of the OFCI model. Before I want to give a closer view on the OFCI model, I want to give a more detailed introduction into the topic. Thus, first I would like to briefly introduce the main constructs of the recent work: Intelligence and Openness. Afterwards, I would like to examine a few models that deal with the influence of personality on the development of intelligence. I will take a closer look at one of these models, the OFCI model by Ziegler and his colleagues (2012). In particular, I will focus on the Environmental Enrichment Hypothesis of the OFCI model, which states that Openness manifests in activities that positively influence cognitive development in adulthood. Extended by the concrete activities, reading and calculating, the basic theoretical model of this work is created. This model will be tested in two studies. The aims are to examine (1) the generalizability for adults of all ages and (2) the specific effect in the situation after job loss. After the presentation of the studies, the model will be discussed and implications will be shown.

Disambiguation of Main Constructs: Openness and Intelligence

Intelligence

Looking at people's performance, intelligence is the most important construct in psychology to differ people along a dimension of their general capability. A number of influencing researchers in intelligence agree that intelligence is defined as "very general mental capability that, among other things, involves the ability to reason, plan, solve problems, think abstractly,

comprehend complex ideas, learn quickly and learn from experience. It is not merely book learning, a narrow academic skill, or test-taking smarts. Rather, it reflects a broader and deeper capability for comprehending our surroundings- 'catching on,' 'making sense 'of things, or 'figuring out 'what to do." (Gottfredson, 1997, p. 13)

There is a long history of research proposing models about specific abilities underlying the general construct intelligence (e.g. Cattell, 1943; Schneider & McGrew, 2018; Vernon, 1965). A recent model is the The Caroll-Cattell-Horn model of intelligence (CHC) by Schneider and McGrew (2018). Several important models are included here to draw a bigger picture of intelligence. The model assumes intelligence as a capability that can be separated in broad and narrow abilities. Broad factors include fluid reasoning, acquired knowledge, domain-specific sensory abilities, memory, and speed. More specific abilities can be found within the broader domains.

The CHC model integrates several important models of intelligence research. This also includes an important idea by Cattell, which is also used in the current work. According to Cattell, intelligence could be divided into two components, namely fluid intelligence (Gf) and crystallized intelligence (Gc). The main difference is described as followed: "If you are unfamiliar with a problem, you can apply reason to find a solution. If you have seen the problem before, you simply need to recall whatever solution was successful in the past. These two ways of solving problems, deliberate reasoning and recalling past solutions, correspond to what Raymond Cattell (1941, 1943) called Gf and Gc, respectively." (Schneider & McGrew, 2018, pp. 89-90). Recent work is based

on intelligence described by the separation of Gf and Gc. Before elaborating this point, I want to give a short introduction to Openness as the second main construct in this work.

Openness

Openness is one of the Big Five personality traits (other four traits: Extraversion, Neuroticism, Agreeableness, and Conscientiousness). The nature of this trait has been discussed a lot since its postulation. Openness is seen from different perspectives as being connected to adaptiveness (Specht, Egloff, & Schmukle, 2011), explorative behavior (DeYoung, Grazioplene, & Peterson, 2012), and intellectual interests (e.g. Goldberg, 1999). Depending on the specific focus of the definition, Openness is also Openness to Experience, Culture, Intellect, or Openness/Intellect. A clearer picture is drawn by recent research, indicating that Openness can be divided into two broad factors (DeYoung et al., 2012): The differentiation is based on neuropsychological findings. Thus, one part of Openness called "Intellect" shares some brain structures with intelligence. The other part is the aspect "Openness" (hereinafter referred to as "aspect Openness"). This aspect is associated with brain functions related with perception of patterns. What is special about this is, that both aspects are highly intercorrelated, but Intellect is not associated with perception of patterns, and the aspect Openness is not associated with Intelligence. Why both domains are still so highly associated is unclear. However, the whole trait Openness includes both aspects. Thus, Openness is a general willingness to engage with new stimuli. So, it is a good starting point for learning new things.

This is also supported by the fact, that Openness plays an important role in the development of intelligence Ackerman, 1996; Von Stumm & Ackerman, 2013(Baker & Bichsel, 2006; Bühner, Kröner, & Ziegler, 2008; Furnham &

Cheng, 2016; Von Stumm, Deary, et al., 2011; Wettstein, Tauber, Kuźma, & Wahl, 2017; Zhang & Ziegler, 2015; Ziegler et al., 2012). However, not all facets of Openness are of same importance when also examining intelligence. The traditional facet model of Openness (e.g. McCrae & John, 1992) includes openness to ideas, openness to aesthetics, openness to fantasy, openness to feelings, openness to actions, and openness to values. However, for the interplay with intelligence openness to ideas seems to be of higher importance (Ziegler et al., 2012).

Theories about the Influence of Openness on Intelligence

The last section introduced Openness as a personality trait that is associated to intelligence. Now, I want to give an overview over important theories explaining the cognitive development influenced by Openness (amongst other factors). I will start with Cattell's Investment Theory, which was already introduced more than 50 years ago. Afterwards more recent models follow: First, Ackerman's PPIK (1996) model is introduced, as well as the related model about Investment Traits (e.g. Von Stumm & Ackerman, 2013). The Intellect framework of Patrick Mussel (Mussel, 2013) follows. Moreover, I want to introduce the trait-activation model (Tett & Burnett, 2003) as an important basis of the current work. Finally, I set focus on the OFCI model, which is the baseline model of this dissertation.

Investment Theory

Cattell's Investment Theory (Cattell, 1943, 1947, 1987) is linked directly to his distinction between Gf and Gc (see also in section about intelligence). This distinction states that Gf is based on biological processes, whereas Gc

should grow with the experiences someone makes during development. But both facts are highly correlated. Cattell explains this high correlation with their developmental linkage: the investment of Gf in developing of Gc.

The main idea of the Investment Theory is, that Gf is *invested* in building Gc. Thus, whenever a person comes in a situation with a problem that is unfamiliar, the person has to analyze the complex situation and find a rule that is behind the problem. Thus, Gf is used here. At the same time Gc will grow by adding this new experience including the learning rules for problem-solving, that will help in the next situation where the same problem arises. However, Gf is needed to build Gc, which explains the fairly high correlation between both constructs.

However, the limitation of Cattell's Investment Theory on only these two variables is a much too simple. For instance, Cattell assumes that both the time we spend in learning things, as well as interests play an important role in the development of Gc. These processes were refined and especially focused by Ackerman (1996) in his model about Intelligence-as-process, Personality, Interest, and Intelligence-as-knowledge (PPIK) model. Therefore, I would like to use the perspective of the PPIK model to take a detailed look at these processes.

PPIK Model

Ackerman's model is named after the four main constructs: Intelligence-as-process, Personality, Interest, and Intelligence-as-knowledge (PPIK, Ackerman, 2000; Ackerman & Heggestad, 1997). The model focuses on the development of knowledge acquisition as the most important part of adult

cognitive development (Ackerman, 2000). The model is proposing three main ideas: (1) the distinction between intelligence as a process and as knowledge, (2) knowledge as central component of adult intelligence, and (3) influence of personality and interest on the acquisition of knowledge.

(1) Intelligence-as-process and Intelligence-as-knowledge: Based on Cattell's differentiation between Gf and Gc (see above), Ackerman assumes general intelligence as two broad factors, which are close to Cattell's Gf and Gc (Ackerman, 1996, 2000). One factor is called intelligence-as-process, which is described as "the speeded aspect of intelligence that declines during normal adult development" (Ackerman, 1996, p. 239). It includes Reasoning, Memory Span, Perceptual Speed and Spatial Rotation (Ackerman, 1996). The other factor of intelligence is called intelligence-as-knowledge. Ackerman describes that as a similar but broader construct than Gc: "The natur of intelligence-as-knowledge matches the first description of Gc provided by Cattell in his Investment Theory (but much broader than common assessment techniques for Gc)" (Ackerman, 2000, p. 241). This knowledge is seen as most important component ("dark matter", p. 240) of adult intelligence (Ackerman, 2000). Thereby, especially domain-specific knowledge is considered as important. "Such domains include: knowledge associated with academic study (e.g., science, music, art); knowledge associated with active engagement in society (e.g., knowledge about the operation of the government); knowledge about the world around us (technology, law); knowledge associated with occupations; and knowledge associated with avocational hobbies" (Ackerman, 2000, p. 96).

(2) Knowledge as "dark matter" of adult intelligence: Ackerman claims that learning in adulthood is characterized less by uniform learning situations than it was in childhood at school (Ackermann, 1996, Ackermann, 2000). But rather, acquiring knowledge in adulthood would be characterized by learning experiences during occupational (and non-occupational) activities. Knowledge accumulation develops along the lines of vocational interests. Because of this process each person builds up a very specific knowledge structure that represents their abilities, but is difficult to compare with other peoples ' knowledge structures.

(3) Interplay of personality/interests and cognitive ability: Ackerman's PPIK model assumes an idiosyncratic build-up of knowledge in adulthood. This knowledge build-up is characterized by the interplay of ability and personality/interests. The higher the ability of a person, the higher the probability to solve a specific task successfully. The aspect "personality/interests" affects the motivation to try to solve the task. The interest in a task grows with increasing ability. Non-solving a task is followed by a decrease in interest in this task area. Thus, specific abilities are shaping the interests and personality of a person, the previous interests/personality, but also the further development of specific abilities. This results in certain "trait complexes" (see Ackerman, 2000). Each complex includes personality, interests, and specific abilities, showing positive commonalities, e.g. intellectual/cultural trait complexes including Openness, Gc, and artistic as well as investigative interest.

Ackerman's PPIK model proposes hypotheses about the interplay of ability and personality. On the basis of the investment trait model was developed (e.g. Von Stumm & Ackerman, 2013). This framework focuses on personality traits, which are associated with intellectual engagement. This also includes Openness. Since Openness is the focus of the current work, this theory will also be briefly outlined.

Investment-Traits

The framework about investments traits (see Von Stumm, 2013; von Stumm, Chamorro-Premuzic, & Ackerman, 2011) adopts the idea of *investment* described by Cattell's Investment Theory also (see above). Building upon this, it is assumed that specific personality traits determine where, when and how people invest their Gf. These traits are called investment traits. These are defined as "stable individual differences in the tendency to seek out, engage in, enjoy, and continuously pursue opportunities for effortful cognitive activity" (von Stumm, Chamorro-Premuzic, et al., 2011, p. 225).

Investment traits can be clustered in traits that are more similar to each other (Von Stumm & Ackerman, 2013). These clusters differ from each other in their content focus of intellectual engagement. For example, there is an investment trait that catches the difference in hunger for knowledge and engagement in cognitively stimulating activities (intellectual curiosity), whereas another refers to the preference for activities engaging problem-solving (e.g. cognitive puzzles), but do not actively explore new situations (abstract thinking). Another trait complex encompasses especially explorative behavior rather than cognitive stimulation, which focuses on a more general search for varied and

new stimuli. Furthermore, there is a trait complex that focuses on immersion while engaging in activities (absorption). The tolerance of uncertainty or the enjoyment in vague situations as an important part of intellectual engagement is included in another trait cluster (ambiguity). Another complex focusses on sensitivity and perception of the environment by including especially aesthetic awareness and open imagination (Openness). Furthermore, it is assumed that investment traits differ regarding the aspect of the cognitive result they influence. So, some investment traits influence Gc, academic performance, the result of a college entry test, or a person's knowledge. Openness is seen as an important factor for the acquisition of Gc.

This framework is based on the fact that personality traits are related to intellectual engagement. While the framework of investment traits clusters these traits, another theory tries a completely different approach: The Intellect framework (Mussel, 2013) also looks at personality traits related to cognitive development. However, it assumes that these are only facets of a broader trait. Intellect is proposed to be that broader trait. This theory is also be briefly outlined.

Intellect Framework

Mussel (2013) introduced a framework about personality factors that influence intellectual achievement. Intellect is defined as a "dispositional individual difference variable involving behavior, intentions, affect, attitudes, and mental processes, related to intellectual performance, such as problemsolving, thinking, information search, learning, or creativity" (Mussel, 2013, p. 886). He assumes that "personality factors that influence intellectual

achievements, especially in relation to and interaction with cognitive abilities" can be brought together in the Intellect framework. All constructs refer to specific dimensions of Intellect. There are two dimensions: The *process* and the *operation* dimension.

The process dimension refers to the motivational component of Intellect. There are two different motivational orientations: seek and conquer. Seek is about the "affective aspects and general Openness that accompanies approaching situations that are intellectually engaging" (Mussel, 2013, p. 886) Conquer refers to the "motivational tendencies once such situations have been encountered and includes aspects such as effort, diligence, persistence, and working hard to resolve incongruities and master intellectual challenges"(Mussel, 2013, p. 886).

The operation dimension includes three aspects: think, learn, and create. Think is based on behavior such as reasoning, drawing conclusions from premises, recognizing relations between elements, and dealing with complexity. A person with a high score on the think facet "will appreciate thinking about theories, engaging in problem-solving behavior, analyzing complex situations, or puzzling for hours over a problem"(Mussel, 2013, p. 886). Learn refers to "motivational processes that are associated with acquiring crystallized intelligence"(Mussel, 2013, p. 886). Thus, a person scoring high on the learn facet will show preferences for and engage in gathering and understanding new information and seeking new knowledge; they are interested in a wide variety of topics and issues and want to know everything about them. Create refers to a "persons 'ability to produce creative outcomes" (Mussel, 2013, p. 886) (i.e.,

products that are novel and useful). This aspect is about contributing toward creative intellectual achievements in precisely that sense. Individuals with high levels on the create facet have preferences for developing new ideas, concepts, strategies, and products. They like to search for novel and unusual solutions for problems and improve processes and products. By contrast, individuals with low levels on the create facet are more likely to apply existing and known procedures, products, and processes.

The intellect framework and the investment traits are models that specifically deal with personality traits related to intellectual behavior. Openness appears in both works: Openness is assumed to be personality traits fostering intellectual engagement in both. The next model also includes the influence of personality on behavior, but we leave the specific context of intellectual situations. More precisely, the model is based on the idea that behavior of a person in a specific situation is not only predicted by their personality, but also by the characteristics of the situation itself.

Trait activation model

The trait activation model (Tett & Burnett, 2003) assumes that behavior in a specific situation is determined by a person's personality as well as by the characteristics of the situation itself. The behavior determined by a personality trait would only be shown if certain characteristics of the situation match that trait. However, the two main ideas of trait activation are: (A) the situation needs enough degrees of freedom for individual behavior and (B) the trait expression has to fit the situation.

(A) According to the first idea, it is proposed that situations differ according to whether they leave much room for individual behavior (weak situation) or not (strong situation). Very strong situations would be those in which the behavior of a person is determined by the situation and less by the characteristics of a certain personality trait. For illustration of this distinction the example of a burning house can be used. In this situation it does not depend on a personality trait whether a person is leaving the burning house. The situation (here, the fact that the house is burning) determines the behavior of people. To summarize, the first idea of trait activation is that there are different degrees to which situations can influence a certain behavior.

(B) The second idea of trait activation is that the specific character of a situation has to match the expression of personality trait. According to the character of a situation, a work situation can be viewed from three different perspectives. First, from the perspective of the task to be performed, e.g. how much accuracy is required for this task. Then, there is also the perspective of the

team, e.g. how much communication with the others is required or also how much unity. In addition, a work situation can always be viewed from the perspective of the organization. Thus, the general organization culture is also important. In summary, different aspects of a situation can determine the expression of personality traits.

However, the actual behavior is also set in relation to performance (work performance). A performance can be described as more or less fitting to the situation. In doing so, the characteristics of a situation are again taken into account. People can reflect on their achievement after the conclusion of a project, for example by asking themselves whether they made sufficient efforts. The motivation triggered by this (extrinsic motivation) can influence the behavior shown. Furthermore, there is intrinsic motivation more driven a persons personality itself.

In summary, the behavior of individuals depends on the one hand on the situation (shaped by the strength and nature of its character) and on the other hand on the motivation to change behavior (shaped by the performance/achievement and motivation due to personality). The behavior itself is also influences the situation because people change their environment. Therefore, people tend to choose situations that correspond to their personalities. In the present work, I apply the idea that the activation of a personality trait depends on the situation. Before I elaborate on this thought, I will introduce the most important basic model of this work, the OFCI model.

Openness-Fluid-Crystallized Intelligence (OFCI) model

The Openness-Fluid-Crystallized (OFCI) model (Ziegler, Cengia, Mussel, & Gerstorf, 2015; Ziegler et al., 2012; Ziegler, Schroeter, Lüdtke, & Roemer, 2018) describes the interplay of Openness, Gf, and Gc. The connections between these variables are illustrated in two ways. On one side there is the immediate performance perspective and on the other the developmental perspective. Whereas the developmental perspective focusses on the influence of one variable on the development of another, the immediate performance perspective considers the current interplay of all three variables. Beyond these three interacting variables, the OFCI model includes interests and critical life periods as influencing variables. In the following section the immediate performance perspective will be presented first, then the developmental perspective, and finally further variables of the model.

Immediate relations of the constructs within the OFCI model

The immediate performance perspective in the OFCI model considers the associations between the traits Openness, Gf, and Gc. It is assumed all three traits are positively intercorrelated: A high level in one trait goes along with a high level in the others. Like Cattell (see above), a high level of Gf is associated with a higher level of Gc. Furthermore, more open people tend to be more intelligent and more intelligent people tend to be more open. This association of Openness with cognitive abilities does not apply equally to all Openness facets. Openness to ideas plays the most important role for the association with cognitive abilities.

The associations between Openness and Gc and between Gf and Gc are independent (Ziegler et al., 2012). This means that Openness and Gc are still

associated even when the association with Gf is controlled for. The same goes for the relationship between Gf and Gc (controlled for Openness). But there is an exception called the *Dominance Effect* (Zhang & Ziegler, 2015; Ziegler et al., 2012). This effect describes how Gf or Openness above a certain level leads to the disappearance of the influence of the other variable on Gc. This means for people with a high level in Gf that there is no effect of Openness on Gc. The same holds true for highly open people: there is no effect of Gf on Gc.

Explanations for these relationships can be found in the developmental interplay of all three variables. It is assumed that Openness has a positive developmental influence on both Gf and Gc. The positive influence also works the other way around: higher levels of cognitive abilities also positively influence the development of Openness. A more detailed description of the effects follows in the next section.

Investment Theory, Mediation Hypothesis, and Environmental Enrichment Hypothesis

The OFCI model incorporates several ideas about the longitudinal relations of the main constructs Openness, Gf, and Gc. The effect from Openness on cognitive abilities can be divided into following effects: (A) an effect of Gf on Gc (*Investment Theory*), (B) an effect of Openness on Gc via mediation over Gf (*Mediation Hypothesis*), and (C) an influence of Openness on cognitive abilities via Environmental Enrichment (*Environmental Enrichment Hypothesis).*

The *Investment Theory* of the OFCI model is based on the idea of Cattell's Investment Theory. The basic idea here is, that Gf needs to be invested

to build up Gc. The authors argue: “simply experiencing new situations might not be sufficient to gather Gc” (Ziegler et al., 2012, p. 174). It would be necessary to use Gf “to make sense of the situation” (Ziegler et al., 2012, p. 174). Thus, Gf can only grow by experiencing a new situation. For processing this new situation Gf is necessary. This process results in broader Gc.

In the OFCI model the Investment Theory is expanded by the idea that people differ in the likelihood to get into new situation and therefore new experiences. The likelihood of experiencing a new situation is influenced, amongst others, by the personality trait Openness. More open people are “curious, imaginative, willing to deal with new themes, and eager to learn” (p. 174). Therefore, the authors assume, a more open person “spends more time trying to figure out new problems or learning new things” (p. 174). Because Gf is needed to master such novel situations, Openness “opens up more opportunities to train this specific cognitive ability” (p. 175). This effect is called *Environmental Enrichment* and based on the Environmental Enrichment Hypothesis by Raine and Reynolds (2002).

As mentioned at the beginning of this work, they proposed that there is a positive influence of stimulation seeking behavior of very young children on their cognitive development. This means that young children who are seeking more stimulation enrich their environment by these experiences, which fosters their cognitive development. The main idea is, that children search new experience, which they have to master. To master new situations, cognitive abilities are needed and therefore trained during this process. Ziegler and his colleagues (2012) interpret the children’s ’behavior as an indicator for

“curiosity” (p.175). The reason for different behaviors is based on the different personalities of the children (more or less curious children). To apply the Environmental Enrichment Hypothesis to adulthood Ziegler and colleagues assume that there is also a trait that describes individual differences in seeking new experiences. This trait is assumed to be Openness.

However, Ziegler and collogues (2012) propose a positive influence of the personality trait Openness on cognitive development. Openness goes along with an increased likelihood for new experiences and therefore an enriched environment can be build. This environment is characterized by new situations, which can be mastered by using Gf. As the result, broader Gc is built. Thus, Openness positively influences Gf and because Gf helps build up Gc also Gc is positively influenced by Openness. The positive effect of Openness on Gc via Gf is called *Mediation Hypothesis*.

Environmental Success Hypothesis

Additionally, the OFCI model assumes the idea of a positive influence of Gf on Openness. Ziegler et al. (2012) propose that the “experience [of mastering new and unknown situations] in turn should positively influence interest in new situations and thus the development and expansion of Openness” (p. 175). The likelihood of success should be higher for more intelligent people (Ziegler et al., 2018). Thus, a higher intelligence leads to an increase in Openness. This effect is called *Environmental Success Hypothesis*. The interplay of intelligence, positive feeling, and Openness is based on associations in brain function found by (DeYoung, Peterson, & Higgins, 2005). Openness is associated with brain functions that are modulated by dopamine. Dopamine

increases the activities of brain regions associated with novelty, more flexible information processing, and memory retrieval. Ziegler and his colleagues derive from these results that "successfully dealing with new challenges should go hand in hand with a feeling of joy and pride" (Ziegler et al., 2012). As a consequence people might seek such rewarding situations, which then in turn leads to an increase in Openness.

Moderators within the OFCI model

Ziegler and his colleagues add two more variables to the OFCI model that influence the interplay between Openness, Gf, and Gc. These variables are (A) critical time periods and (B) interests. Both operate as moderators within the OFCI model. This means that people who differ in one of these variables are affected differently by the effects described in the OFCI model. In that manner critical time points affect Environmental Enrichment Hypothesis and Environmental Success Hypothesis. In case of interests, the Investment Theory as well as the Mediation Hypothesis is impacted. The following sections will give an introduction of these impacts and explanations of the mechanisms behind them.

Critical time periods: Effects of age and life events

According to the OFCI model, critical time points have a moderating influence on the Environmental Enrichment Hypothesis and on the Environmental Success Hypothesis. That means, the effect of Openness on Gf as well as vice versa is more impactful in special time periods of a person's life. To be more specific, it is assumed that the impact is highest in young and late adulthood. This moderation effect depends on life events that are typical for

these ages. Young adulthood as well as late adulthood are times of change. In young adulthood people start families and new jobs, in late adulthood people are retiring and losing their partner. Ziegler et al. (2012) refer to Roberts, Walton, and Viechtbauer (2006) who found that these critical times are associated with changes in personality and are typical in early and late adulthood.

Ziegler and colleagues (2012) assume critical life changes like leaving home for university or a job, starting to work, finding new friends, starting a long-term relationship, and being more economically independent from their parents present many opportunities for learning. The mechanism behind this effect unfolds because people are thrown into new and unknown situations that offer many possibilities for Openness to work. The fewer possibilities to develop Openness are happening in a person's life (i.e. new, unknown situations), the less Openness can unfold. Thus, the extent of the positive effects (Environmental Enrichment Hypothesis and Environmental Success Hypothesis) is directly related to these critical time periods or to specific ages (ages typical for critical time periods).

Interests

The influence of interests is included as well in the OFCI model and is described by the Investment Theory. According to that interests moderate the influence of Gf on Gc. This means that the strength of the developmental effect depends on certain interests. Ziegler et al. share Ackerman's opinion that "interests have a profound influence on the development of knowledge" (Ziegler, 2012, p. 182). Ackerman describes interests as motivational aspects that determine the orientation toward specific knowledge domains (Ackerman,

1996). So, dependent on interests, the investment of a limited resource like Gf will lead to deeper or broader knowledge of certain domains. In the OFCI model, interests act as strengthener of the described effects. The long-term influence of interests can be explained at the situation level. The OFCI model is described by Ziegler, Schroeter, Lüdtke, and Roemer (2018) from situational perspective. More open people perceive a situation more likely as a learning situation and would engage with that situation. Interest positively influences this effect of Openness in situations, where characteristics match the person's interest.

The Current Framework: An Extended Environmental Enrichment Hypothesis

The current framework (see figure 1) is based on the Environmental Enrichment Hypothesis within the OFCI model (e.g. Ziegler et al., 2012). Like the model by Ziegler and colleagues (2012) the proposed Environmental Enrichment Hypothesis is used to describe the cognitive development of adults. The focus lays on the interplay between personality trait and intelligence; it is assumed Openness would positively influence the development of cognitive abilities. Furthermore, the current framework extends this idea. So, Openness would manifests in activities at work and during leisure time. These cognitive activities would influence cognitive development. Concretely, the new information would train cognitive abilities. Thus, main constructs of this extended Environmental Enrichment Hypothesis are Openness as personality trait and intelligence (Gf and Gc). Openness is seen as an influencing variable, while intelligence is the effected variable. As with Ziegler (2012), Openness and intelligence are seen as closely associated constructs (especially via common brain structures), but to be separated (see also DeYoung, 2012).

In congruence to research of Ziegler (e.g. Ziegler et al., 2012), Ackerman (e.g. Ackerman, 1996) and von Stumm (e.g. von Stumm &Ackermann, 2011), Openness is seen as the personality trait influencing cognitive abilities. Even if the whole spectrum of this trait is thought to be important for a positive influence on cognitive abilities, the effect described by Environmental Enrichment Hypothesis is more driven by the Intellect aspect than the Openness aspect. This assumption is in accordance with Ziegler and

his colleagues (e.g. Ziegler et al., 2012; Ziegler et al., 2018). Like the Environmental Enrichment Hypothesis, Openness is assumed to drive people into new situations. By that way people would come more likely into learning situations. The second main construct in this current framework is intelligence. As in the OFCI model, Gf and Gc are chosen to represent the intelligence. In accordance with the Investment Theory (e.g. Cattell, 1987), Gf is seen as the ability to be used in new and unknown situations. Gc is seen as strategies resulting from this experience, which would be applied in similar situations. The developmental aspect of Investment Theory is also applies here. This means that Gc grows by the use of Gf. This is also in accordance with Environmental Enrichment Hypothesis by Ziegler and his colleagues (2012).

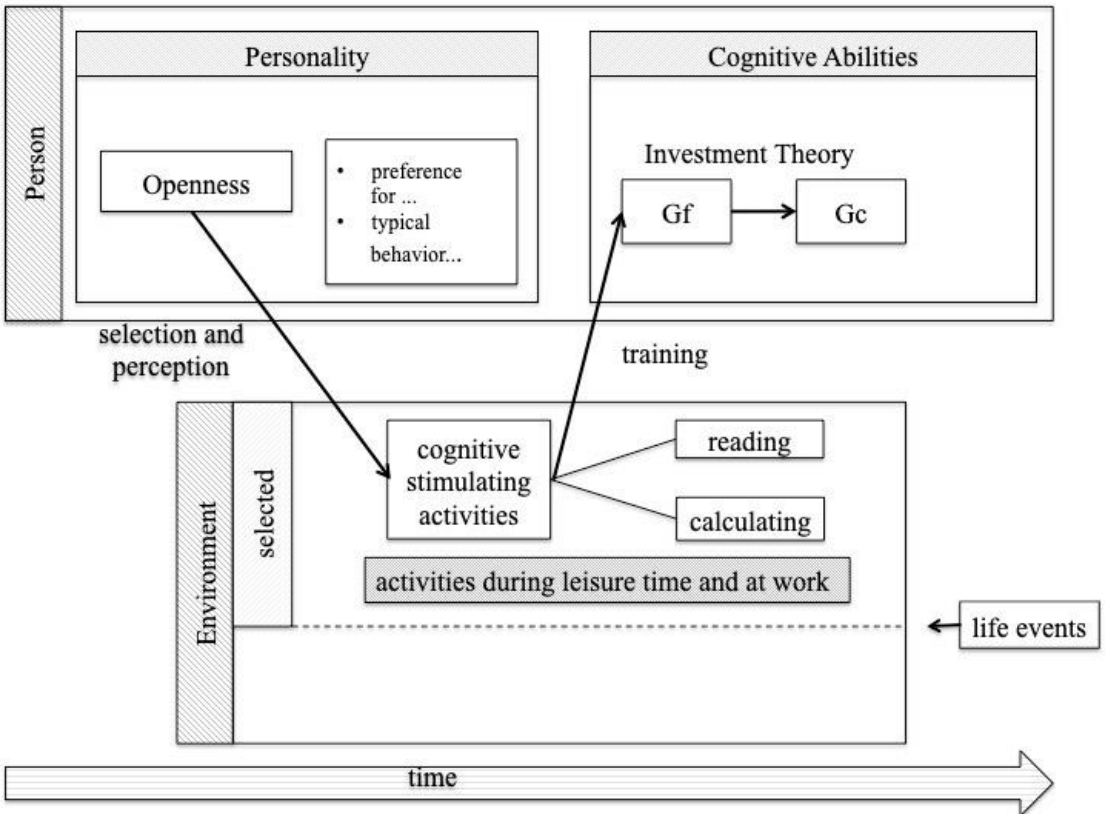

Figure 1 : The Environmental Enrichment Hypothesis of the OFCI model extented by activities at work and during leisure time

The main idea of the current work is that Openness would influence the development of cognitive abilities by environmental enrichment. Thus, the hypothesis proposes a developmental effect of Openness on cognitive abilities (Ziegler, 2012). Even if the environmental enrichment effect can be considered for a single situation (see Ziegler 2018), a more global picture is assumed here. Furthermore, the effect includes a mediation effect by activities at work and during leisure time. This idea was not tested yet, but is in accordance with ideas proposed by the OFCI model (Ziegler, 2012, 2015). However, the current models assumes that Openness would manifest itself in the way people shape their lives. Concretely, activities at work and during leisure time would be opportunities of shaping one's life. It is assumed that people decide for a certain activity during their leisure time or for a certain job in accordance to their Openness. This idea is based on the trait-activation theory (Tett & Burnett, 2003). Thus, it is assumed that certain activities at work and during leisure time could be distinguished by their challenging character and that this would interact with the personality. In this way, personality and work and leisure activities would adapt to each other in the long term. Concretely, it is assumed that more open people tend to choose a job and activities during leisure time, which they have to deal with new information.

Furthermore, the aspect of critical lifespans will be focused in the current work. According to the OFCI model (e.g. Ziegler, 2012), the influence of Openness is more effective in times of change. During these times likelihood of facing an unknown situation increases (Roberts et al., 2006). Thus, in more rigid

times, the effect is lower. This can be explained by trait-activation (Tett & Burnett, 2003). Thus, the likelihood for Openness to manifest in activities increases, when the environment can be perceived as intellectually challenging. In times of change new situations are more likely and by that way open behavior is activated.

As mentioned above, the current framework includes Gf and Gc as important parts of intelligence. Both variables are connected by idea of investment theory (e.g. Cattell, 1943). Thus, Gf is used to build up Gc (see also above). Furthermore, the current model shares another assumption with OFCI model (e.g. Ziegler, 2012): So, only Gf is directly influenced by Openness. This is congruent with the idea of Openness's effect on the environment. Thus, Openness increases the likelihood of facing with new situations. To master unknown situations, Gf is used. Thus, the enriching effect of Openness fosters only Gf in a direct way. However, Gc is indirectly influenced. By solving a new problem using Gf, Gc grows. This means, there is no direct effect of Openness on Gc by environmental enrichment.

Research Questions

The main interest of the current work is to take a closer look at the influence of the personality trait Openness on one's cognitive development. Concretely, the Environmental Enrichment Hypothesis of the OFCI model (e.g. Ziegler, 2012) is focused. This hypothesis assumes that the effect of Openness on cognitive development is due to an environmental enrichment of Openness. Thus, more open people would create themselves an environment full of new situations and so enriched by learning opportunities fostering cognitive development. The developmental effect of Openness on cognitive development could be shown in prior studies using samples of adults of young (Ziegler et al., 2012) and old age (Ziegler et al., 2015). The current work wants (1) to test the generalization of the effect for adult ages and (2) prove the specific assumption of environmental effects within the Environmental Enrichment Hypothesis by extending the described effect by the mediation through activities at work and during leisure time.

Thus, first aim is to generalize and test the Environmental Enrichment Hypotheses of the OFCI model (Ziegler, 2012). The Environmental Enrichment Hypothesis is described crucial for adult cognitive development. However, the effect is based on mastering new situations serving as learning situation, which serve as training for Gf and Gc. There are critical timespans associate with more changes (Roberts et al., 2006) and so with a higher likelihood of new situations. The critical timespans would be associated with young and old adult ages. Prior studies about Openness's influence on cognitive development tested the effect with samples of young and older adults or show an ambiguous picture about the

effect (Hülür, Gasimova, Robitzsch, & Wilhelm, 2018; Wettstein et al., 2017; Ziegler et al., 2015; Ziegler et al., 2012). Thus, recent work wants to find out, if the hypothesis is valid in a sample representative for all ages.

Furthermore, the current work wants to go beyond these prior studies (mentioned above) using models of Openness and developmental association with intelligence as evidence for Environmental Enrichment Hypothesis. Thus, the second aim is to look closer at concrete assumption behind the environmental enrichment. Therefore, the previously model including an effect of Openness on cognitive abilities will be extended by a mediation through activities at work and during leisure time. Activities selected as job and as leisure time activity are traced back on Openness's influence on the environment. Furthermore, the activities are assumed to be associated with intelligence. Both aspects together have to be considered to find out, if Openness is involved in creating an environment fostering cognitive abilities (as assumed by Environmental Enrichment Hypothesis of the OFCI model).

To examine these main questions, the current dissertation included different studies. The articles about these studies are presented next.

Running Head: MECHANISMS OF ENVIRONMENTAL ENRICHMENT

The Openness-Fluid-Crystallized-Intelligence (OFCI) Model and the Environmental Enrichment Hypothesis

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Abstract

The Openness-Fluid-Crystallized-Intelligence (OFCI) model describes how these different constructs interact over time. One fundamental element in the model is the Environmental Enrichment Hypothesis, which states that more Openness leads to more learning opportunities, thereby fostering fluid intelligence (Gf). Indirectly, this positive influence also has a positive effect on crystallized intelligence (Gc). Despite empirical evidence supporting the model as a whole, little is known with regard to the actual mechanisms underlying environmental enrichment. PIAAC (Programme for the International Assessment of Adult Competencies) data (N = 5,465) were used to explore possible behavioral differences that lead to enriched environments for more open people. To this end, we utilized different indicators of reading and calculating behavior. The indicator of Openness used was indeed found to be associated with differences in reading and calculating activities at work and during leisure time. These relations were also shown to be related to the indicator of Gf and indirectly to the indicator of Gc. Theoretical implications and limitations of the study are discussed.

Keywords: Openness, reading, calculating, Gf, Gc

According to Cattell's Investment Theory (1987), fluid intelligence (Gf) promotes the growth of crystallized intelligence (Gc). Further, in Ackerman's (1996) model about Intelligence-as-Process, Personality, Interests, Intelligence-as-Knowledge (PPIK model), intelligence is considered a process, and personality traits, especially Openness and interests, are added as important factors of intellectual development. On the basis of these ideas, Ziegler, Danay, Heene, Asendorpf, and Bühner (2012) developed the Openness-Fluid-Crystallized-Intelligence (OFCI) model, which includes the relationship between Gf and Gc and assigns a central role to Openness. More specifically, Openness is thought to play a key role in one central aspect of the OFCI model: the Environmental Enrichment Hypothesis.

This hypothesis states that Openness fosters the development of Gf. It is assumed that higher Openness leads to more training opportunities, which in turn enrich the environment so that Gf develops positively. However, research has yet to determine which specific behaviors differ in the lives of open people compared with less open people and affect the development of Gf. The aim of the current study was to shine light into this black box by analyzing cross-sectional data from the Programme for the International Assessment of Adult Competencies (PIAAC) study. The next sections describe the OFCI model, the PIAAC study, and how the PIAAC data were used to test the ideas about behavior involved in the Environmental Enrichment Hypothesis.

The OFCI Model

Figure 1 provides a brief overview of the main hypotheses in the OFCI model. The model is divided into two parts. One side presents current relations

between abilities and Openness. Specifically, Openness and Gf affect Gc in a positive way. Thus, the higher a person's Openness, the higher the person's Gc. The same holds true for Gf in that high Gf is associated with more Gc. However, there is also an interaction effect in the form of a compensating effect. This dominance effect says that not only are the traits additive, but they also compensate for each other at high levels. So, the effect of one variable disappears just as the other variable exceeds a certain level. Ziegler and his colleagues found this relation in their paper on the OFCI model (2012). Zhang and Ziegler (2016) replicated these results in a large sample of Chinese students across three different content areas.

However, of even greater importance for the current investigation is the second part of the OFCI model, which deals with the interplay between Openness, Gf, and Gc that takes place over time. From this longitudinal perspective, the path from Gf to Gc represents Cattell's *Investment Theory*. Recent theories (Van Der Maas et al., 2006; Van Der Maas, Kan, Marsman, & Stevenson, 2017) and empirical work (Kievit et al., 2017) have introduced the idea of mutualism as a cause for cognitive development. The general idea here is that there are multiple basic cognitive abilities facilitate each others' growth over time. While this idea supports the path from Gf to Gc, it also suggests that a path from Gc to Gf is equally likely. Moreover, this theory points towards the need to analyze more basic abilities and their interaction with each other and with Openness over time. The current study strongly focuses on possible mechanisms underlying Environmental Enrichment and therefore, does not contribute directly to this interesting debate.

Next to this just described path, there are three more paths leading to hypotheses regarding the role of Openness in the model. The *Environmental Success Hypothesis* says that persons with higher ability (Gf) will manage new situations more successfully, and as a consequence of having a positive feeling of success, they are more likely to search for new situations to master in the future (for further supporting evidence see Wettstein, Tauber, Kuźma, & Wahl, 2017). Thus, Gf is considered to influence the development of Openness.

Another path specifies the opposite influence. The idea behind the *Environmental Enrichment Hypothesis* is based on findings by Raine, Reynolds, Venables, and Mednick (2002), who suggested that Openness should provide more learning opportunities and should consequently foster Gf. In addition, Gc should be indirectly affected via this mechanism (*Mediation Hypothesis*). Empirical support for this longitudinal perspective of the OFCI model has been provided by longitudinal data from people in early (Ziegler et al., 2012) and late adulthood (Ziegler, Cengia, Mussel, & Gerstorf, 2015). Theories describing cognitive development as influenced by gene-environment interactions strongly support the idea that personality manifestations altering the environment can cause cognitive development due to gene activation (e.g., Dickens & Flynn, 2001).

Despite this positive support for the general ideas of the OFCI model, it remains unclear exactly how differences in Openness enrich a person's environment and thereby foster Gf. So far, no studies have focused on actual behaviors. It is simply assumed that Openness fosters the development of Gf by making people with higher degrees of Openness select more unknown situations

that require Gf to be solved successfully. The current study focuses on the possible mechanisms that lead to enriched environments as posited in the OFCI model. Identifying such mechanisms is an important step in understanding how differences in Openness shape the development of cognitive abilities.

It has to be stressed here that the OFCI model focuses on Openness but does not explicitly refute the idea that other personality traits might be related to cognitive development as well. So far, there is little empirical evidence supporting the idea of other traits than Openness to be influential. This was elaborated in a review by Curtis, Windsor, and Soubelet (2015).

Openness and Environmental Enrichment

The Big Five trait Openness and its nature has been discussed a lot since its postulation. Openness is seen from different perspectives as a personality trait, that is connected to adaptiveness (Specht, Egloff, & Schmukle, 2011), explorative behavior (DeYoung, Grazioplene, & Peterson, 2012), and intellectual interests (e.g. Goldberg, 1999). Depending on the specific focus of the definition, Openness is also Openness to Experience, Culture, Intellect, or Openness/Intellect. In the OFCI model Openness is seen as a personality trait, that energizes people to actively search for new information and new situations as well as a preference for dealing with new information (Ziegler et al., 2012). This definition sets a focus on Openness to Ideas, which former studies of the OFCI model show to be more important than the other Openness facets. That facet is also a defining one in the Openness aspect Intellect. Despite this seeming importance of Openness to ideas or Intellect, we want to note, that we consider

the whole domain as important for the OFCI model framework (Ziegler, Schroeter, Lüdtke, & Roemer, 2018).

Openness as a Predictor of Reading and Calculating Behavior

Reading is positively associated with Openness. Kraaykamp and Van Eijck (2005) analyzed the 1998 and 2000 waves from the Family Surveys of Dutch Populations (N = 3,156, ages 18 to 70) to examine the impact of the Big Five on media preferences and cultural participation. Using regression analyses, they found that Openness predicted reading as a preferred leisure activity. In addition, their results showed that "individuals who score high on Openness clearly favor complex and stimulating genres (literature and suspense literature), while they dislike romantic fiction" (p. 1683). Furthermore, reading is an important part of Typical Intellectual Engagement (Arteche, Chamorro-Premuzic, Ackerman, & Furnham, 2009; Wilhelm, Schulze, Schmiedek, & Süß, 2003), a trait that can be seen as one of the facets of Openness (Mussel, 2013). Arteche et al. (2009) reported a correlation between Openness and reading of r = .27 in a sample of 328 students from universities in the US and UK. In addition, Openness was found to correlate with investigative interests (Costa, McCrae, & Holland, 1984). People with intellectual interests value the development and acquisition of knowledge and prefer a job environment where they can do these things, such as in mathematical or scientific work (Holland, 1996, p. 398). This finding is supported by a meta-analysis by Barrick, Mount, and Gupta (2003). Their results showed a moderately strong correlation between Openness and investigative interests.

In summary, we suggest here that one of the mechanisms by which Openness leads to environmental enrichment is that Openness is manifested in

differences in reading and calculating activities. In particular, higher Openness should lead to more of these activities.

In the OFCI model, it is also suggested that Openness is about seeking new ideas and situations or information in general. More open people are more likely to select new situations seeking new stimuli, which train Gf because, for example, evaluation and integration of these new stimuli are necessary to deal with new information. This investment of Gf into the understanding and integration of new information is associated with increasing Gc (i.e., acquiring knowledge about the situation that had previously been new). So, this knowledge is associated with specific characteristics of the new information, for example, the new information people obtain when visiting a zoo will extend their knowledge about animals (e.g., by understanding the difference between rabbits and hares and integrating this into one's knowledge structures).

As shown above, Openness affects the choice of one's reading material with people higher in Openness favoring intellectually stimulating genres. It can be assumed that the information contained in such material includes new information that needs to be understood and integrated. With regard to the OFCI model, we therefore expect that not only will reading be related to Openness but that it will also act as a mediator between Openness and Gf and thereby between Openness and Gc. Considering the domain specificity of Gc (Schipolowski, Wilhelm, & Schroeders, 2014), it is further expected here that these relations will mostly occur for verbal aspects of Gc.

Despite the lack of empirical evidence regarding similar processes between Openness and calculating, it is reasonable to expect similar

mechanisms to be at work. Again, referring to the faceted nature of Gc, these relationships are expected to occur primarily for the numeracy-related aspects of Gc. This idea will be explored in the analyses of this paper.

PIAAC

The Programme for the International Assessment of Adult Competencies (Rammstedt, 2013; Zabal et al., 2014) is a long-term study initiated by the Organization for Economic Cooperation and Development (OECD), which focuses on the development of adult competencies and is conducted by the Leibniz Institute for Social Science (GESIS). Thereby, the concept of the survey is based on people's real lives. So, priority is given to the skills required in the labor market that are important for accessing resources and services in society in general. The first wave of the PIAAC study focused on the competencies literacy, numeracy, and problem solving in technology-rich environments (PS-TRE). These were chosen as a representative subset of the skills focused. Next to these competencies, PIAAC includes variables that influence the development of skills. Therefore, a lot of information about education, family background, personality, as well as activities during leisure time and at work (e.g., reading and calculating) has been collected to create a comprehensive picture of each person's competences and behaviors in real life.

PIAAC Constructs and the OFCI Model

PIAAC and research on the OFCI model pursue a common goal: the clarification of the development of cognitive abilities. Even though the term competence is used in PIAAC, there is a strong conceptual overlap with

cognitive abilities. Koeppen, Hartig, Klieme, and Leutner (2008) defined competence as "domain-specific cognitive dispositions that are required to successfully cope with certain situations or tasks, and that are acquired by learning processes" (p. 68). Moreover, several theoretical papers have come to the conclusion that competencies and abilities share variance and strongly overlap (Monnier, 2015; Wilhelm & Nickolaus, 2013). Finally, it has been suggested that competencies represent continuous traits rather than dichotomous or categorical classes (Blömeke et al., 2014; Blömeke, Gustafsson, & Shavelson, 2015). Thus, PIAAC data work well for testing hypothesis generated from the OFCI model regarding cognitive abilities, even though the competency measures are not pure cognitive ability tests.

As already mentioned, next to the more cognitive-ability-like competencies, PIAAC also includes some variables that could influence the development of these abilities, including information about how much a person engages in reading and calculating activities. This study specifically focuses on certain parts of the OFCI model and therefore needs: (a) an indicator of Gf, (b) an indicator of Gc, and (c) an indicator of Openness to Ideas. At the same time, the study tries to shed light on the potential mechanisms that underlie environmental enrichment by integrating (d) information about reading and calculating activities as concrete behaviors that are expected to differ between people with high versus low Openness. Therefore, we used the abilities measured in PIAAC as indicators of fluid and crystallized intelligence and information from the background questionnaire to operationalize Openness and reading and calculating behaviors. The next sections describe the extent to which

competencies measured in the PIAAC can be seen as indicators of the constructs in the OFCI model.

Fluid Intelligence: Problem Solving in Technology-Rich Environments (PS-TRE)

Problem solving (PS-TRE, PIAAC Expert Group in Problem Solving in Technology-Rich Environments, 2009) served as an indicator of Gf in this study. According to the PIAAC Expert Group in Problem Solving in Technology-Rich Environments (2009), problem solving in technology-enriched environments involves the use of digital technology, communication tools, and networks to acquire and evaluate information, communicate with others, and perform practical tasks. It is said that the cognitive processes needed to solve the tasks are (a) goal setting and progress, (b) planning and self-organizing, (c) acquiring and evaluating information, and (d) making use of information. These processes, especially the last two, strongly resemble the definition of fluid intelligence given by McGrew (2009): "the use of deliberate and controlled mental operations to solve novel problems […]. Mental operations often include drawing inferences, concept formation, classification, generating and testing hypothesis, identifying relations, comprehending implications, problem solving, extrapolating, and transforming information" (p. 5). Furthermore, Greiff et al. (2014) summarized recent research about problem solving and concluded that problem solving is an important part of fluid intelligence. In addition, Bühner, Kröner, and Ziegler (2008) supported the idea by showing a strong overlap between indicators of Gf and indicators of problem solving.

Crystallized Intelligence: Literacy and Numeracy

In this paper, we used literacy (PIAAC Literacy Expert Group, 2009; Rammstedt, 2013; Zabal et al., 2014) and numeracy (PIAAC Numeracy Expert Group, 2009; Rammstedt, 2013; Zabal et al., 2014) as indicators of Gc. The PIAAC Literacy Expert Group (2009) defines literacy as "understanding, evaluating, using and engaging with written text to participate in society, to achieve one's goals and to develop one's knowledge and potential" (p. 8). Literacy tasks usually include a text as the stimulus and one or more questions about the text that can often be answered by highlighting parts of the text. With regard to the PIAAC Literacy Expert Group (2009), cognitive processes that are needed to answer questions accurately are (in order of difficulty) (a) access and identify, (b) integrate and interpret, and (c) evaluate and reflect. According to McGrew (2009, p. 5) reading and writing (Grw) include, amongst others, reading, decoding, and reading comprehension and are part of Gc in Carroll's Three Stratum Model. In addition, Schroeders, Bucholtz, Formazin, and Wilhelm (2013) showed that a latent comprehension factor based on reading and viewing comprehension can be accounted for to a great extent by science knowledge. Therefore, we used literacy as an indicator of Gc in this study.

In addition to literacy, we used numeracy as another indicator of Gc. The PIAAC Numeracy Expert Group (2009) defines numeracy as "the ability to access, use, interpret, and communicate mathematical information and ideas, in order to engage in and manage the mathematical demands of a range of situations in adult life" (p. 6). Numeracy tasks consist of figures, tables, or texts

as stimuli and questions that can be solved with the help of a calculator. The numerical result has to be entered into a field next to the question. The cognitive processes needed to answer questions accurately are (in order of difficulty): (a) identify, locate, and access, (b) act upon use, (c) interpret, evaluate, and analyze, and (d) communicate. Rindermann, Flores-Mendoza, and Mansur-Alves (2010) substantiated the use of numeracy as an indicator of Gc. They argued that the quantitative relations that are needed to solve tasks involve knowledge learned in school. According to McGrew (2009), Carroll included math achievement factors in the abilities that fall in the domain of knowledge and achievement. In the Carroll-Horn-Cattell model, this factor is called quantitative knowledge and "represents an individual's store of acquired mathematical knowledge, not reasoning with this knowledge" (McGrew, 2009, p. 6). Thus, there is sufficient support for choosing numeracy as a further indicator of Gc.

Operationalization of Openness, Reading, and Calculating Behavior

The PIAAC study focuses not only on cognitive abilities but also on variables that could influence the development of these abilities. Among these variables is information about peoples' personality, including information about a person's typical behavior regarding learning situations as well as the amount of reading and calculating they tend to engage in. The information fits well with the OFCI model because it includes a personality measure that is indicative of Openness as well as measures of concrete behavior that could underlie environmental enrichment.

The OFCI model promotes the role of Openness in the development of Gf and Gc (Ziegler et al., 2012). Thus, regardless of the specific terminology

(see above), it is important for the operationalization of Openness to describe a person as curious about new information or situations, actively searching for new information, and having a preference for dealing with new information. In the PIAAC survey, there is a scale called learning strategies (Allen et al., 2013), which consists of six items that closely reflect this personality description (e.g., "I like learning new things" and "When I come across something new, I try to relate it to what I already know"). All six items can be found in Table 1. Based on the opinions of the involved authors, these items were judged to capture Openness and specifically Intellect. The latent correlation of this measurement of Openness and the Openness score derived from the Short Big Five Inventory (BFI-S, Lang, John, Lüdtke, Schupp, & Wagner, 2011) from the 2014 PIAAC wave was $r = .51$ which further supports this notion. In fact this matches the meta-analytically based convergent validity of Openness test scores (Pace & Brannick, 2010).

PIAAC also focuses on concrete behavior that could influence the development of cognitive abilities such as numeracy, literacy, or PS-TRE. To achieve this, the background questionnaire includes questions about intellectual behavior at work and during leisure time. The frequency of different reading and calculating activities at work and during leisure time is assessed. Regarding reading activities, questions are about reading (a) directions and instructions, (b) letters, memos, and mail, (c) newspapers or magazines, (d) professional journals or publications, (e) books (fiction or nonfiction but not for one's job or school), (f) manuals or reference material, (g) financial statements, and (h) diagrams, maps, or schematics. Questions about calculating include information about the frequency with which one (a) calculates costs or budgets, (b) uses or calculates

fractions or percentages, (c) uses a calculator, (d) prepares charts, graphs, or tables, (e) uses simple algebra or formulas, and (f) uses advanced math or statistics. In this study, the information about reading and calculating activities was used as a mediator between Openness and Gf, thereby testing for the specific, theoretically informed mechanisms that could underlie environmental enrichment.

Aims of the Study

The OFCI model is a process model describing the developmental interplay between Openness, Gf, and Gc. One aim of this study is to produce the expected relations using population-representative data from the PIAAC study. In this paper, we specifically focus on one part of the OFCI model: the Environmental Enrichment Hypothesis. We suggest that Openness has a positive influence on Gf by providing an enriched environment with more training opportunities. Through its influence on Gf, Openness is also expected to indirectly influence Gc. The OFCI model, including the Environmental Enrichment Hypothesis, has been previously supported (Ziegler et al., 2015; Ziegler et al., 2012). However, the specific mechanisms underlying environmental enrichment have not been tested.

This study tries to provide first ideas about such mechanisms by looking at reading and calculating. Both activities have been shown to be related to Openness and can be considered as cognitive tasks. In line with this idea, we test two models in this paper. The difference between the two models is that in the first one, reading mediates the effect of Openness on cognitive abilities, where literacy is the indicator of Gc. In the second model, calculating activities are the

mediator in a model in which numeracy is the indicator of Gc. In both cases, we distinguish between activities at work and during leisure time.

In addition, we also test a model with a more general indicator of Gc. In this model, the two indicators (i.e., numeracy and literacy) are combined into one latent variable for Gc. Also, both mediators (i.e., reading and calculating) are included in the model as latent variables in order to control for potential overlap. This more general model is used to compare reading and calculating as mediators. In addition, the specific activities (e.g., reading books or magazines) are compared in the model to obtain a better understanding of the environmentally enriching effects of reading and calculating activities.

Method

Sample and Procedure

In this study, we used data from the German PIAAC sample (Rammstedt, 2013; Zabal et al., 2014). PIAAC compares job-specific competencies of adults across different countries in regular waves. The first wave was collected in 2012. These data were used here.

The German PIAAC sample consisted of adults between the ages of 16 and 65 years, thus representing the occupationally active population. Data collection was based on a two-stage stratified and clustered sampling design. In the first stage, municipalities, and in the second stage, individuals were randomly selected from registry data. Nationality, resident status, or language skills did not impact a person's selection. The data included 5,465 persons who

were representative of Germans between the ages of 16 to 65 years (Rammstedt, 2013; Zabal et al., 2014).

One hundred twenty-nine trained interviewers administered the tests in participants' homes. The first part of the procedure was a personal standardized interview that measured background information. After the interview, competencies were measured on a computer or, in cases where the person was not able to handle a computer mouse, with a paper-pencil-test. The assessment was organized in modules. In the first module, items from one of the three domains (i.e., literacy, numeracy, or PS-TRE) were selected. In the second stage, one of the remaining domains was chosen. During the assessments, participants worked on their own. Interviewers monitored their progress and provided the materials. There was a time restriction for the tasks. On average, 80 to 95 min were needed for the whole assessment, with between 30 to 45 min taken up by the background questionnaire.

Measures

Ability measures.

Crystallized intelligence: literacy and numeracy. The literacy tasks included a text as the stimulus material and one or more items that asked questions about the text and could often be answered by highlighting parts of the text (PIAAC Literacy Expert Group, 2009; Rammstedt, 2013; Zabal et al., 2014). Altogether, the literacy assessment included 52 items. The numeracy tasks (PIAAC Numeracy Expert Group, 2009; Rammstedt, 2013; Zabal et al., 2014) consisted of figures, tables, or text as the stimulus materials and items that

could be solved with the help of a calculator. The numerical result had to be entered into a field next to the question. Altogether, the numeracy test included 52 items. We used all 52 items here to specify a measurement model for each variable.

Problem Solving in Technology-Rich Environments (PS-TRE). Problem solving in technology-rich environments (PS-TRE) included 24 items in 14 scenarios that have to be solved with a computer (PIAAC Expert Group in Problem Solving in Technology-Rich Environments, 2009; Zabal et al., 2014). All 24 items were used here to specify the measurement models. An example for such a scenario is provided by OECD (2012): Participants see a webpage with the title "websearch", that includes links to five different job portals. To solve the question, that is displayed next to the window with the webpage, they have to use tools and functionalities of webpages (e.g. clicking on a link). In that case, they have to find out, which portals do not require registration or paying fees and mark the appropriate links to give the answer to the question (for further information see (OECD, 2012)).

Background questionnaire. The background questionnaire (Zabal et al., 2014) was developed by the International Consortium (Allen et al., 2013). General information was recorded on, for example, a person's age and gender as well as details about (a) education and training, (b) recent and current work, and (c) social background. In addition, the actual use of certain skills at work and during leisure time was illuminated. This last information given in the background questionnaire was used in our study as (a) indicators of Openness

and (b) to specify habits that represent environmental enrichment (i.e., reading and calculating behaviors).

The background questionnaire included six items that refer to a person's typical behavior in learning situations. Specifically, every item is a statement about a person's habits in dealing with problems and tasks that have to be rated regarding the person's own standing on these behaviors (1 = *not at all*, 5 = *to a very large extent*). All six items can be found in Table 1.

Another part of the background questionnaire asked participants how often they typically carry out certain tasks at work, for example, how often they work with colleagues (1 = *never*, 5 = *every day*). The questions we focused on here were about reading (e.g., frequency of reading books at work) and handling numbers (e.g., frequency of drawing diagrams). These topics were also the subjects of questions about leisure activities. Both scales, calculating at work and calculating during one's leisure time, were operationalized by six items each. All items were about the specific use of calculation habits (e.g., "Outside your work, how often do you usually prepare charts, graphs or tables?"). Eight other items were used to assess reading skills at work and during leisure time. These items asked for specific reading habits (e.g., "In your current job, how often do you usually read articles in newspapers, magazines, or newsletters?"). All questions, for reading as well as for calculation skills, were answered with frequency information (1 = *never*, 2 = *less than once a month*, 3 = *more than once a month and less than once a week*, 3 = *more than once a week but not daily*, 5 = *daily*).

Descriptive statistics and reliability estimates for all variables can be found in Table 2.

Statistical Analyses

We used R (R Core Team, 2014b) to compute all analyses (data were imported using the package foreign, R Core Team (2014a). Descriptive statistics were calculated with the package psych; (Revelle, 2014). The main focus of the analyses was to test the structural equation models (implemented with the package lavaan; Rosseel, 2014). The analyses were divided into several steps. The starting point of this process was to test the measurement models for literacy, numeracy, and PS-TRE. In a next step, we tested the measurement models for the indicator of Openness as well as for the skills. Finally, for reading and calculating, one model each was created for activities at work and one each for activities during leisure. In addition, we estimated a weighted McDonald's Ω_w (Brunner & Süβ, 2005) for all latent variables.

After testing all measurement models, we tested the structural models. Three different models were of interest (Models A, B, and, C, see Figures 2 - 4). All models represented the complete OFCI model. Thus, the relation between the indicator of Openness and the indicator of Gc mediated by the indicator of Gf was common to all models, and problem solving served as the indicator of Gf in all models. Furthermore, the models specifically focused on the relations potentially underlying environmental enrichment. In order to achieve this, we specified an indirect effect of the indicator of Openness on the indicator of Gf that represented activities leading to environmental enrichment. Model A (see Figure 2) specified reading as a mediator and included literacy as an indicator

of Gc in order to account for the faceted nature of Gc. The effect of calculating activities as a mediator between the indicator of Openness and the indicator of Gf was the focus of Model B (see Figure 4). Here, numeracy was used as an indicator of Gc. Next to the specific approaches tested in Models A and B, the last model was more general. Model C (see Figure 6) specified one latent variable Gc with the two indicators of Gc (i.e., numeracy and literacy) also used in the prior models. Also, both mediators (i.e., reading and calculating) were specified. Model C included comparisons of all four indirect paths from Openness to cognitive ability. In addition, two-sided confidence intervals (α = .05) were calculated for all of the loadings of the reading and calculating items to distinguish the importance of specific activities in environmental enrichment in the OFCI model. In each model, we also tested the complete indirect path from the indicator of Openness to the indicator of Gc, reflecting the idea underlying the mediation hypothesis.

To maximize power for all following analyses, we utilized the complete sample and dealt with missing data by using a full information maximum likelihood method. At the same time we estimated power using the package semTool (Pornprasertmanit, Miller, Schoemann, & Rosseel, 2013) for the structural equation model with the worst RMSEA. This procedure is based on MacCallum, Browne, and Sugawara (1996) and tests the power to detect a critical RMSEA difference. For the current analyses, the worst RMSEA was .139. The power to detect a critical difference to the threshold of .06 was approximately 1.

The assessment of the goodness-of-fit of all models was guided by Hu and Bentler (1999) recommendations. Thus, the Comparative Fit Index ($CFI \approx .95$), the Standardized Root Mean Square Residual ($SRMR \leq .09$), and the Root Mean Square Error of Approximation ($RMSEA \leq .06$) were used. In case of model misfit, model alterations were specified to ensure that the parameters we interpreted were not biased by model misfit (Heene, Hilbert, Draxler, Ziegler, & Bühner, 2011). To minimize the risk of overfitting the model to the data, any model alterations were also guided by therorical considerations about the reason for misfit. At the same time, despite the large sample, this approach also potentially reduces generalizability to other samples.

Results

First, we present the measurement models. Then, we present the results of our tests of the different structural models. Descriptive statistics of all latent variables are shown in Table 2.

Measurement Models

Table 3 shows the model fits for all measurement models. Standardized path coefficients can be found in the Appendix (Table A).

As can be seen, the fit for the measurement model for the indicator of Openness was not acceptable before adding a correlation between two of the six residuals. Both items referred to an analyzing aspect (to get to the bottom of difficult things and to figure out how different things fit together). The correlation between the two residuals was r = .34. The standardized path coefficients of all manifest variables ranged from β = .58 to β = .72. The construct reliability of the indicator of Openness was Ω_w = .80.

Also, for literacy, a modified model was specified because the model consisting of 52 manifest variables without any correlated errors yielded an unacceptable model fit. A correlation between two item residuals had to be added. Both items belonged to the same item block and thus referred to the same text (Lakeside Fun Run). The correlation between these residuals in the modified model was r = .63. Standardized path coefficients ranged from β = .18 to β = .71. The construct reliability of literacy was Ω_w = .95.

The measurement model for numeracy had an acceptable fit without modifications. For numeracy's items, the standardized path coefficients ranged from $\beta\lambda$ = .20 to β = .66. In the case of PS-TRE, they ranged from β = .46 to β = .70. The construct reliability for numeracy was Ω_w = .94, and for PS-TRE, it was Ω_w = .89. Thus, modified models for the indicator of Openness and literacy

as well as the specified models for numeracy and PS-TRE yielded acceptable fits.

For the models for reading (at work and during leisure), modified models were constructed by adding error correlations between similarly worded items (Model A: reading books and manuals; Model B: reading magazines and professional journals). The same applied to the models for calculating at work and during leisure time, for the items preparing charts and using advanced mathematics as well as calculating budgets and using fractions/percentages. In addition, for calculating budgets at work and using a calculator at work, we added an error correlation. As Table 2 shows, the final models had an acceptable fit. Standardized path coefficients ranged from $\beta = .44$ to $\beta = .75$ for reading at work, from $\beta = .26$ to $\beta = .63$ for reading during leisure time, from $\beta = .36$ to $\beta = .80$ for calculating during leisure time, and from $\beta = .46$ to $\beta = .80$ for calculating at work.

Model A: Reading as a mediator. Model A (see Figures 2) illustrates the influence from the indicator of Openness via problem solving as indicator of Gf through to literacy. The model includes a direct path from the indicator of Openness on literacy.

Model A (Figure 2) had an adequate model fit (see Table 4). The effect of the indicator of Openness on reading at work was descriptively smaller ($\beta = .40$) than the one on reading during leisure time ($\beta = .58$). The same held true for the impact of these variables on problem solving: reading at work ($\beta = .15$) had a smaller effect than reading during leisure time ($\beta = .34$). All indirect as well as direct paths were significant ($p < .001$). In addition, it can be seen that

the direct influence from the indicator of Openness to literacy was strongly reduced by the mediations (from β = .32 to β = .11[1]) but remained significant. As expected, literacy was related to problem solving (β = .83). These results support that the impact of the indicator of Openness on problem solving as an indicator of Gf and indirectly on literacy as an indicator of Gc was partially mediated by reading at work and during leisure time. Thus, the higher persons score in the indicator of Openness, the more they read at work and during their leisure time, which goes along with higher ability in PS-TRE as an indicator of Gf and also with higher literacy.

Model B: Calculating. As can be seen in Figures 4, Models B tested the path from the indicator of Openness to numeracy mediated via calculating behaviors and problem solving. The model fit was acceptable (see Table 4). Model B revealed an indirect (β = .29) as well as a small direct (β = .14) path of the indicator of Openness to numeracy as the indicator of Gc. The relation between the indicator of Openness and the frequency of calculating activities was moderate for both calculating activities at work (β = .35) and calculating activities during leisure time (β = .38). Also the impact of calculating activities on problem solving was moderately high for both ways of using numerical skills (β(work) = .23, λ(leisure) = .31). Like all other paths in the model, both indirect paths were significant ($p < .001$). As expected, the impact of problem solving on numeracy was high (λ = .75). This result suggests that the impact of the indicator of Openness on the indicator of Gf and indirectly on the indicator of Gc is mediated by calculating activities at work and during leisure time. Higher

[1] This is a zero-order correlation. See also Table 5.

scores in the indicator of Openness were associated with more calculating activities during leisure time and to a job that requires more calculating activities. This enhanced use of numerical skills was associated with higher ability in problem solving and with higher numeracy.

Model C: General model. Model C, as illustrated in Figures 4 (see Table 4 for the model fit), combines the different mediators and different indicators of Gc from Models A and B. Thus, the indirect impact of the indicator of Openness on that broader indicator of Gc is mediated by the two types of reading and calculating as well as by problem solving. The model fit was acceptable. Gc loaded literacy (β = .96) as well as numeracy (β = .91). There was a small but significant direct effect from the indicator of Openness to the indicator of Gc (β = .11). The zero-order correlation between the indicator of Openness and the indicator of Gc was .32. Looking at the impact of the indicator of Openness on reading and calculating activities, it could be seen that reading during leisure time (β = .59), reading at work (β = .46), calculating at work (β = .42), and calculating activities during leisure time (β = .40) were moderately related to the indicator of Openness. The impact of these variables on problem solving ranged from β = .11 for calculating at work and reading during leisure time, to β = .17 for reading at work, to β = .25 for calculating in leisure time. All paths in the model were significant (p < .001). The zero-order correlations between the behaviors and the indicator of Gc can be found in Table 5. Similar to Models A and B, the relation between Gf and Gc was high (β = .85). The path from the indicator of Openness to the indicator of Gc was mediated by all behaviors used to a comparable degree (reading at work: $\beta_{a1*b1*c}$ = .07, reading during leisure

time: $\beta_{a2*b2*c}$ = .07, calculating at work: $\beta_{a3*b3*c}$ = .04, reading during leisure time: $\beta_{a4*b4*c}$ = .09, all comparisons: p >.001).

We were also interested in which concrete reading and calculating activities were most important in the OFCI model. Thus, we compared the loadings for the reading and calculating items. In the case of reading during leisure time, reading diagrams, maps, or schematics (β= .67, 90% CI [.58, .76]), manuals or reference material (β = .59, 90% CI [.51, .67]), and professional journals or publications (β = .59, 90% CI [.50, .68]) were most representative, followed by reading letters, memos, and mail (β = .51, 90% CI [.43, .59]), directions and instructions (reference path, β = .48), newspapers or magazines (β = .34, 90% CI [.28, .41]), and books (β = .32, 90% CI [.23, .41]). Least important was the reading of financial statements (β= .24, 90% CI [.19, .30]). For reading at work, a different picture emerged: Most representative for reading were reading letters, memos, and mail (β = .74, 90% CI [.62, .87]), and professional journals or publications (β = .73, 90% CI [.62, .83]), followed by reading newspapers or magazines (β = .72, 90% CI [.60, .84]), manuals, or reference material (β= .60, 90% CI [.51, .70]), diagrams, maps, or schematics (β= .54, 90% CI [.44, .64]), directions and instructions (reference path, β = .48), and books (β = .47, 90% CI [.39, .54]). Least important here was reading financial statements (β = .46, 90% CI [.36, .56]). In the case of calculating activities, the picture was similar for work and leisure: Most relevant were activities such as using simple algebra or formulas (leisure: β = .78, 90% CI [.62, .93], work: β = .81, 90% CI [.69, .94]), and using or calculating fractions or percentages (leisure: β = .75, 90% CI [.61, .89], work: β = .80, 90% CI [.69, .91]). Less important activities during leisure time were preparing charts, graphs,

or tables (β = .67, 90% CI [.57, .77]), using advanced math or statistics (β = .59, 90% CI [.50, .67]), using a calculator (β = .55, 90% CI [.44, .67]), and calculating costs or budgets (reference path, β = .38). At work, using a calculator (β = .67, 90% CI [.57, .77]) was the next most important activity after the use of fractions and simple algebra. The preparing of charts, graphs, or tables (β = .64, 90% CI [.55, .72]) and the use of advanced math or statistics (β = .50, 90% CI [.45, .54]) were less relevant. Least important of all of the calculating activities at work was the calculation of costs or budgets (reference path, β = .47).

Beyond the results of the previous models that showed that the influence of the indicator of Openness on indicators of intelligence was mediated by reading (Model A) and numerical skills (Model B), these final results illustrate that both kinds of behaviors used at work and during leisure time are generally important factors. A closer look at specific behaviors showed that not all kinds of reading and calculating behaviors might be equally important though. In the case of reading during leisure time, reading journals, manuals, and diagrams were most relevant, and at work, it was the reading of emails and magazines or newspapers. Regarding calculating activities, there was not a big difference: In both cases, calculations involving fractions or percentage as well as simple algebra were most important.

Discussion

In the current paper, PIAAC data were used to replicate the OFCI model in general and to inspect possible mechanisms underlying the Environmental Enrichment Hypothesis in particular (Openness-Fluid-Crystallized-Intelligence model, Ziegler et al., 2012). The OFCI model was developed by Ziegler and his

colleagues and was based on ideas by Cattell (1987) and Ackerman (1996). Not only is the model about how Gf (fluid intelligence) influences Gc (crystallized intelligence), but it also includes Openness as another key construct in this interplay. The Environmental Enrichment Hypothesis states that Openness positively affects the development of Gf by leading to more learning opportunities. It is assumed that more open persons like to search for new situations and information, thereby stimulating and training their fluid abilities. The longitudinal influence of Openness on Gf has been shown in several studies (Ziegler et al., 2015; Ziegler et al., 2012). However, the concrete mechanisms underlying environmental enrichment have rarely been discussed or tested (but see Ziegler, Schröter, Lüdtke, & Roemer, 2018). The current study distinguished between reading and calculating as two possible mechanisms underlying environmental enrichment. We tested these hypotheses using cross-sectional data. The results support the notion that both activities might underlie environmental enrichment.

Openness, Gf, and Gc

In line with Cattell (1987), we found a strong association of an indicator of Gf and indicators of Gc (numeracy and literacy). According to Cattell, the reason for this is that Gf is invested into the acquisition of Gc. Furthermore, Ackerman (1996) said that personality plays an important role in the development of cognitive abilities. The OFCI model (Ziegler et al., 2012) further suggests that Openness —especially Openness to Ideas—is the crucial personality trait within the context of cognitive development. The results of the current study further support this idea. In all three models, indicators of Gf and

Gc were associated with the indicator for Openness which especially focuses on Openness to Ideas.

Environmental Enrichment Hypothesis

The current study extends previous findings on the OFCI model (Ziegler et al., 2012) by adding a mediator variable between Openness and cognitive abilities to represent environmental enrichment (search for information or situation). In order to prove this idea of mediation by environmental enriching activities, we also tested models, which included direct paths from Openness to ability. Results support a preference for models with these bypasses and so indicate a partial mediation by reading and calculating activities at work and during leisure.

Thus, these results, obtained from cross-sectional data, support the Environmental Enrichment Hypotheses made in the OFCI model. Here, a positive influence of Openness on Gf and Gc is not only described, but also the relation is explained by environmental enrichment, which means that more open people prefer specific environments, which goes along with learning opportunities fostering Gf and Gc. The current results indicate reading and calculating activities at work and during leisure as activities, which can serve as learning opportunities, but also show, that this is only a part of possible activities and by that way gives room for the addition of further activities enriching one's environment. It further has to be noted that we did not test the environmental success hypothesis, which is also part of the OFCI model. That hypothesis states that Openness increases over time due to successfully solving novel situations

based on higher Gf. Future studies therefore need to utilize longitudinal data which will allow to simultaneously model both effects over time.

Specific effects of reading and calculating. Two of the specific activities focused on here are closely related to a specific facet of Gc. Reading is clearly closer to the verbal aspects of Gc (here literacy), and calculating is closer to the numerical or quantitative aspects of crystallized intelligence (here numeracy). Results show that reading (partially) mediates the path from an indicator of Openness to an indicator of Gf. Thus, the hypothesis is supported, that people with higher Openness would read more during their leisure time and at work, and this would foster Gf. Again, the cross-sectional nature of the data must be considered here. Still, this finding is in line with the literature on Openness and similar constructs (Mussel, 2013) and reading activities (Wilhelm et al., 2003). Thus, there is support for the notion that reading might be one important mechanism underlying environmental enrichment.

The current study also shows that the network between Openness, reading, and Gf is also associated with literacy. This finding is in line with the mediation hypothesis from the OFCI model and supports the idea, that environmental enrichment and the investment of fluid ability work hand in hand to shape Gc. The same holds true for calculating and the influence on numeracy. A higher score in the indicator of Openness is related with more calculating activities at work and during leisure time. Thus, calculating activities are associated with higher Gf and thereby with higher numeracy.

In summary, differences in activities such as reading and calculating might be considered results of the manifestation of Openness differences.

Furthermore, these behavioral differences are related with cognitive abilities. This supports the ideas behind the OFCI model, especially the Environmental Enrichment Hypothesis. In particular, the results of the first two tested models showed that even a very specific activity could foster cognitive ability. This means that the search for new information or learning situations can go beyond only activities that have learning as an agenda (e.g., taking a course at night school). It could be an everyday or work-related activity that makes a difference in the development of cognitive abilities. Future research could follow up on this and compare the relations described between different age groups. Reading and calculating, especially the content of the material, might differ between age groups. For example, the material read in schools or by young people in their leisure time might be very different from what retired people read. The influence by Openness could also be different. Ultimately, the effects on Gf and Gc could differ. While Ziegler et al. (2015) confirmed the OFCI model in a late adulthood sample, it remains unclear whether and to what extent the mechanisms implied by the current findings also hold true.

Implications for Crystallized Intelligence in general.

In contrast to previous models, Model C was more general. Instead of looking at the association with a specific indicator of Gc, both indicators were used to model the construct Gc. The results provide support for the original OFCI model, which is about Gc and not only a specific aspect of Gc. Also, both activities, reading and calculating, were included in this model so that comparisons of the influence of the different mediators were possible. The results from this third model show that neither activity is a more dominant

mediator between the indicators of Openness and Gf. The fact that different activities as well as different settings (work vs. leisure) work comparatively well supports another assumption of the OFCI model, which is that environmental enrichment does not have to involve a specific training per se but the general access to new information and situations. Thus, the generalizability of the model is supported.

In addition to the comparison between reading and calculating at work or during leisure time, it is of interest to look more precisely at the activities themselves. By doing so, it becomes clearer what all activities have in common, which is what is specific to the environmentally enriching effect. Results show that for calculating at work and calculating during leisure time, the items that are most representative involve the use of fractions or percentages, thus simple algebra. The use of advanced math is least representative. Thus, the calculating activities that are most likely to enrich the environment and thereby have a positive effect on the development of cognitive abilities might not necessarily be the most challenging tasks of advanced math. With regard to reading, there is a difference between activities done at work and during leisure. In the case of reading at work, the activities that are important include reading emails or notes and articles in newspaper and magazines. Least representative is reading books. Therefore, a high rate of newness is important rather than dealing with one topic in depth. In the case of reading during leisure time, reading professional journals and manuals or reference literature as well as reading diagrams and graphs is most representative, whereas reading financial statements is least representative. These items could indicate the quickly available and well-edited information about a specific topic that helps people learn more about a special hobby (e.g.,

improvement of skills). The OFCI model assumes that environmental enrichment is the search for new information and situations to deal with. Thus, our results fit with these ideas. More specifically, reading activities could provide new information, and calculating activities could offer ways to deal with new information.

Limitations

The current study has a number of strengths, including a sample size of more than 5,000 people who were representative of German adults between the ages of 16 and 65 (Rammstedt, 2013; Zabal et al., 2014). Especially, the large and representative sample fosters generalizability to German speaking populations. However, this study also has a number of limitations.

One of these is that the PIAAC data include no pure indicators of the ability and personality constructs focused here. For example, we used problem solving in technology rich environment (PS-TRE) as an indicator of Gf (fluid intelligence). Indeed, problem solving is a very important part of Gf (Bühner, Kröner, & Ziegler, 2008; Greiff et al., 2014; Schneider & McGrew, 2018), and in this way, can be regarded as a good indicator. At the same time, PS-TRE is not purely measuring Gf, but also Gc. As is the case with many other Gf tests, prior knowledge (e.g., reading or knowing specific symbols) is required. Thus, the association between Gc and Gf could be overestimated in the current study. It has to be stressed though that the Gc measures used contained content differing from the PS-TRE. Thus, overlap is confined to rather basic abilities. Future studies should aim at using purer measures of the abilities to minimize the overlap and test the ideas with more rigorous approaches.

Furthermore, a broader measure of Gf would be advantageous in order to observe the influence of Openness on different facets of Gf. A prerequisite, however, would be for Openness to be measured in an equally broad way as Gf, which was not possible in this study. In the first paper on the OFCI model (Ziegler et al., 2012), the NEO-PI-R (Ostendorf & Angleitner, 2004) was used to measure Openness. Correlational analyses illustrated that the Openness facets differed in their relations to Gf and Gc. In particular, the facets Fantasy, Action, Ideas, and Values seemed to be important. In Study 2 of the same paper, Ziegler and his colleagues looked at the developmental part of the OFCI model. The NEO-FFI (Borkenau & Ostendorf, 1991) was used to measure Openness. Results supported the importance of single Openness facets. Over and above this finding, other authors have shown the diverse relations of Openness facets with ability (Mussel, 2013). The items used in our study to indicate the degree of people's Openness went in the direction of Openness to Ideas. Thus, we used an indicator that focused on the most important facets of Openness in relation to ability. However, the six items indicate only this facet. The same goes for the measurement of crystallized intelligence. The PIAAC data include only numeracy and literacy, which can be used as indicators of Gc. In future research, it might be interesting to investigate which facets of crystallized intelligence are specifically influenced by Openness.

A further limitation is that this study includes only reading and calculating as activities that represent environmental enrichment. The authors of the OFCI (Ziegler et al., 2012) suggested that Openness increases the likelihood of experiencing new learning situations. Reading and calculating are good indicators of activities with learning potential. But there are so many more that

could be of interest. Ziegler and his colleagues (2012) gave a number of possible indicators: “hobbies one has, the number of books one reads, or the number of friends one has. Other behavioral cues could be visits to museums, exhibitions, and concerts, or some kind of actual artistic engagement” (p. 180). By knowing about reading and calculating habits, it is not possible to generalize to the whole spectrum of environmentally enriching habits. Therefore, other activities have to be investigated.

A final but potentially very strong limitation is the cross-sectional nature of the data. The Environmental Enrichment Hypothesis is part of the developmental perspective of the OFCI model. In a cross-sectional design the direction of influence is ambiguous. We wanted to test the Environmental Enrichment Hypotheses, which is about an influence from Openness to cognitive abilities by activities. However, the other direction is equally plausible (Environmental Success Hypothesis within the OFCI model). People with higher cognitive abilities could increase their Openness over time, because of success and enjoyment in learning situations. Thus, both possible directions support the OFCI model and our idea of mediation by activities.

Under the perspective of the Environmental Enrichment Hypothesis, Openness at one time is assumed to influence Gf, so development should be measured at a later time point. To determine whether Gc is influenced directly by Openness and also indirectly via Gf, an additional time point is needed. In this paper, because the environmental enrichment hypothesis was not only assumed but was also defined more precisely, we added a variable to the model to mediate the path from Openness to Gf. By adding this mediating variable, one

additional time point would be necessary to test the complete indirect path. In conclusion, a design with at least four time points would be needed. In this paper, we used PIAAC data that did not dispose of this number of occasions. Therefore, we used the present data to compute cross-sectional analyses of the Environmental Enrichment Hypothesis. However, a longitudinal design is needed and should be implemented in further studies.

Concluding Remarks

In our study, not only were we able to support the OFCI model, but we also looked more precisely at possible activities underlying environmental enrichment and asked the question of what it could be that people do to enrich their environment. The study supports the idea, that people with a higher levels of Openness are more likely to search for more learning opportunities; this fosters their Gf and ultimately affects Gc. These learning opportunities can be found in daily life and in work activities such that reading activities in particular might serve as a source for new information, and calculating activities at work and during leisure time might indicate a more in-depth processing of new information to deal with.

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Tables and Figures

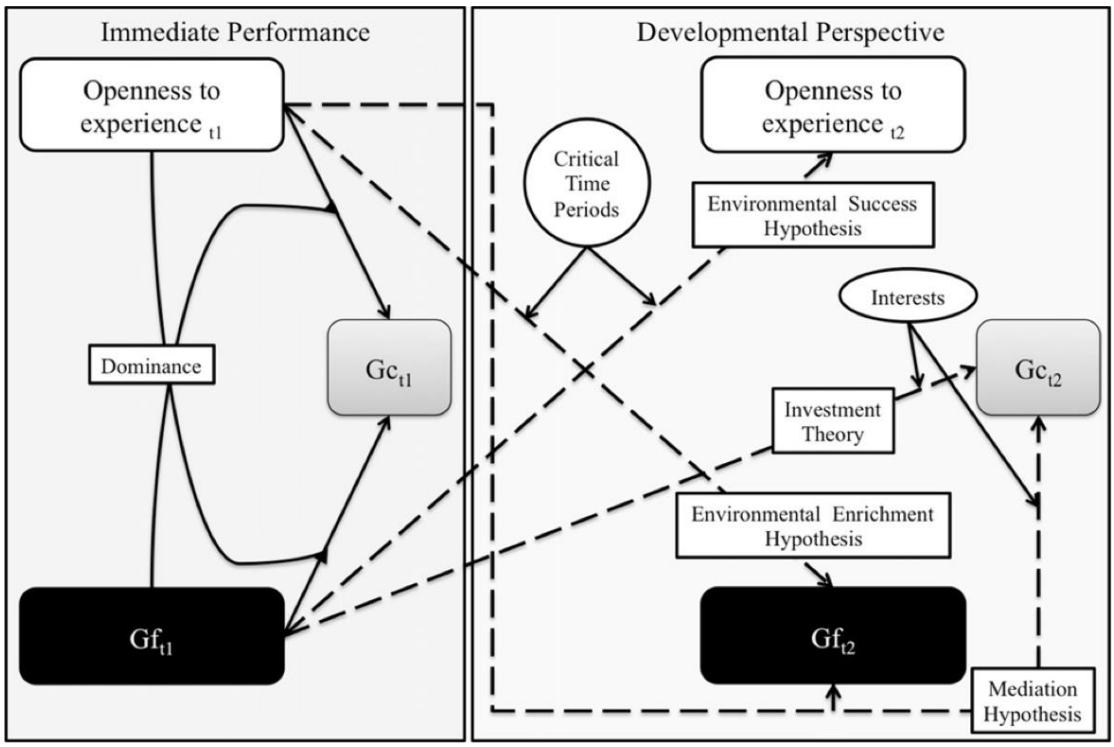

Figure 1: The Openness-Fluid-Crystallized-Intelligence (OFCI) model. Gf= fluid intelligence, Gc= crystallized intelligence. Dashed lines indicate longitudinal influences. Direct influences of each construct on its Time 2 measures are not depicted.

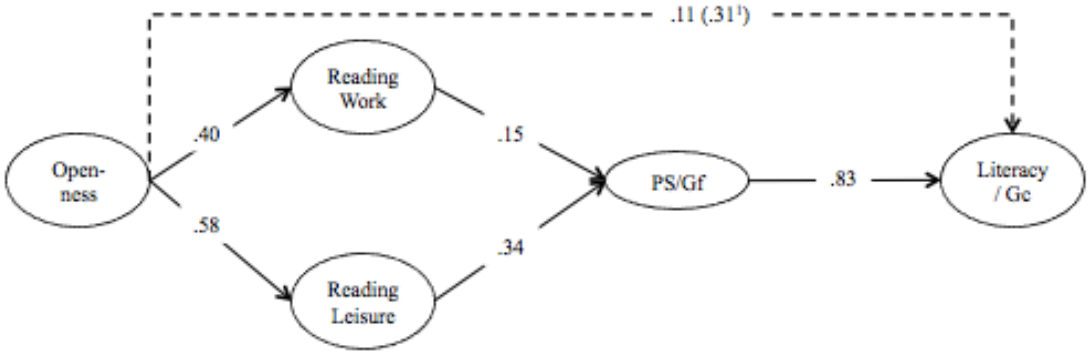

Figure 2: Model A: graphical representation of the model testing the influence of reading on literacy including a direct path from Openness on Gc (but not on Gf). The depicted model does not contain the measurement models. PS= problem solving in technology rich environments, Gf= fluid intelligence, Gc= crystallized intelligence, in brackets the zero-order correlation of the two variables ([1]).

All $p < .01$

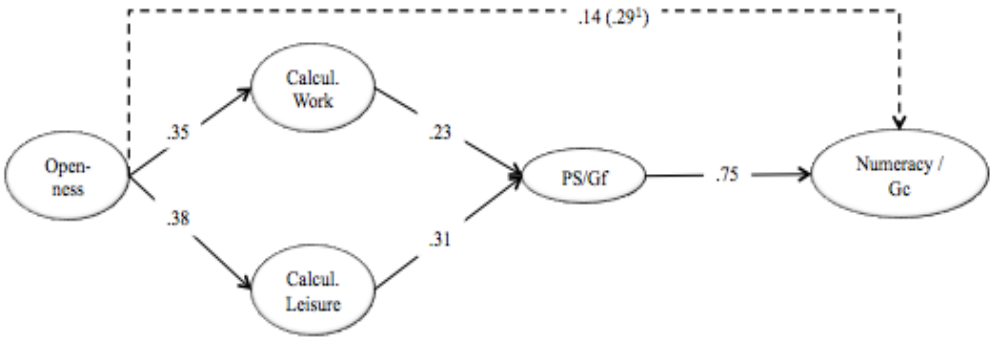

Figure 3: Model B: graphical representation of the model testing the influence of calculating on numeracy within the environmental enrichment hypothesis including a direct path from Openness on Gc (but not on Gf). The depicted model does not contain the measurement models. Calc.= calculation, PS= problem solving in technology rich environments, Gf= fluid intelligence, Gc= crystallized intelligence, in brackets the zero-order correlation of the two variables ([1]).

All $p < .01$.

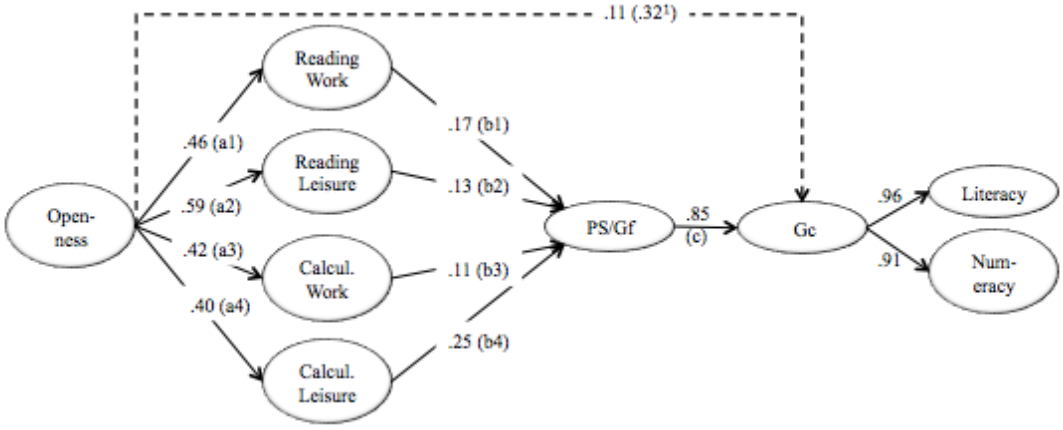

Figure 4: Model C: graphical representation of the environmental enrichment hypothesis with reading and calculation activities as environmental enriching habits including a direct path from Openness on Gc but not on Gf. The depicted model does not contain the measurement models. Calc.= calculation, PS= problem solving in technology rich environments, Gf= fluid intelligence, Gc= crystallized intelligence, in brackets are labels of the paths (a1 –c) or the zero-order correlation of the two variables ([1]). To ensure legibility zero-order correlations of Gc with reading at work (r = .337), reading during leisure (r = .428), calculating at work (r = .368), and calculating during leisure (r = .370) are not included in the figure.

All $p < .01$.

Table 1

Items of learning strategies in PIAAC background questionnaire used as indicators of Openness.

Nr.	*Item text*
1	When I hear or read about new ideas, I try to relate them to real life situations to which they might apply.
2	I like learning new things.
3	When I come across something new, I try to relate it to what I already know.
4	I like to get to the bottom of difficult things.
5	I like to figure out how different ideas fit together.
6	If I don't understand something, I look for additional information to make it clearer.

Table 2

Descriptive statistics.

	Descriptive Statistics				*Intercorrelations*						
Construct	*N*	*M*	*sd*	Ω_w	Num	Lit	PS-TRE	O	RW	RE	CW
Numeracy	4540	.77	.22	.94	1	-	-	-	-	-	-
Literacy	4541	.71	.25	.95	.39	1	-	-	-	-	-
PS-TRE	2240	.77	.52	.89	.32	.28	1	-	-	-	-
Openness	5364	3.58	.63	.80	.15	.13	.2	1	-	-	-
Reading at work	4344	2.71	1.02	.84	.18	.17	.19	.3	1	-	-
Reading everyday	5363	3.16	.69	.74	.18	.21	.26	.41	.44	1	-
Calculating at work	4344	2.35	1.08	.85	.21	.16	.22	.27	.62	.30	1
Calculating everyday	5364	2.20	.81	.83	.2	.17	.27	.3	.22	.49	.35

Note: All statistics (but omega) are based on the row means of all items belonging to a construct. Omega w (Ω_w) is based on the measurement model of the construct. *N*=sample size, *M*= mean, *sd*= standard deviation, Ω_w= construct reliability *McDonald's omega*$_w$, *Lit*= Literacy, *Num*= Numeracy, *PS-TRE*= problem solving in technology-rich environments, *O*= Openness, *RW*= Reading at work, *CW*= calculating at work, *RE*= Reading in leisure, for all correlations: $p<.001$.

Table 3

Model Fits for Measurement models.

		Global model fit			Fit indices		
Construct	*N*	χ^2	*df*	*p*	*CFI*	*RMSEA*	*SRMR*
Numeracy (1)	4540	1642.884	1274	<.001	.966	.008 (.007 - .009)	.049
Literacy(1)	4541	2137.725	1274	<.001	.929	.012 (.011 - .013)	.053
Literacy (2)	4541	1813.781	1273	<.001	.956	.010 (.009 - .011)	.051
PS-TRE (1)	2240	266.121	77	<.001	.964	.033 (.029 - .038)	.031
Openness (1)	5364	714.760	9	<.001	.922	.121 (.113 - .129)	.044
Openness (2)	5364	315.071	8	<.001	.966	.085 (.077 - .093)	.031
Reading in leisure (1)	5363	734.064	20	<.001	.888	.082 (.077 - .087)	.042
Reading in leisure (2)	5363	364.924	18	<.001	.946	.060 (.055 - .065)	.032
Reading at work (1)	4344	1447.407	20	<.001	.869	.128 (.123 - .134)	.058
Reading at work (2)	4344	73.034	18	<.001	.935	.095 (.090 - .101)	.043
Calcul. in leisure (1)	5364	869.732	9	<.001	.909	.134 (.126 - .141)	.048
Calcul. in leisure (2)	5364	11.577	7	<.001	.989	.053 (.044 - .061)	.019
Calcul. at work (1)	4344	769.002	9	<.001	.916	.139 (.131 - .148)	.052

Calcul. at work (2)	4344	173.023	6	<.001	.981	.080 (.070 - .091)	.022

Note: *df*= degrees of freedom. χ^2= chi square value, *p*= probability value of χ^2, *WRMR*=weighted root mean residual, *RMSEA*=root mean error of approximation with 90% confidence interval, *CFI*=comparative fit index, model 1 = model without modifications, model 2= modified model (for modifications see section results)

Table 4

Model fits for structural models.

model	*N*	*χ2*	*df*	*p*	*CFI*	*RMSEA*	*SRMR*	*bic*
Model A	5377	8497.067	3727	<.001	.9040	.015 (.015 - 016)	.052	420227.012
Model B	5377	6774.426	3389	<.001	.9300	.014 (.013 - .014)	.054	345665.080
Model C	5377	24283.278	11298	<.001	.8592	.015 (.014 - .015)	.054	649362.018

Note: *df*= degrees of freedom. χ^2= chi square value, *p*= probability value of χ^2, *SRMR*=standardized root mean residual, *RMSEA*=root mean error of approximation with 90% confidence interval, *CFI*=comparative fit index, model A includes literacy, model B numeracy, and model C literacy and numeracy, models labeled by "+" include an additional direct path from Openness on Gf (for more information, see section Analysis).

Table 5

Zero-order correlations of mediated relations in the models.

Predictor	Criteria	
	Gf	*Gc*
Openness	.273	.319
Reading Everyday	---	.428
Reading Job	---	.337
Calculating Everyday	---	.370
Calculating Job	---	.368

Note: all $p<.01$, *Gf*= fluid intelligence, *Gc*= crystallized intelligence.

Appendix

Table A

Descriptive Statistics for measurement models.

Construct	Item	*estimate*	*std.err*	*std.all*
Reading d. leisure*	H_Q01a	1.000	.000	.512
	H_Q01b	.910	.038	.489
	H_Q01c	.684	.035	.378
	H_Q01d	1.235	.046	.593
	H_Q01e	.755	.044	.318
	H_Q01f	1.195	.043	.628
	H_Q01g	.420	.028	.262
	H_Q01h	1.196	.043	.619
Reading at work*	G_Q01a	1.000	.000	.477
	G_Q01b	1.824	.065	.746
	G_Q01c	1.735	.065	.731
	G_Q01d	1.433	.054	.720
	G_Q01e	.791	.038	.443
	G_Q01f	1.162	.046	.585
	G_Q01g	1.115	.052	.464
	G_Q01h	1.228	.051	.523
Openness*	I_Q04b	1.000	.000	.594
	I_Q04d	1.264	.034	.722

	I_Q04h	1.003	.030	.578
	I_Q04j	1.109	.036	.590
	I_Q04l	1.245	.037	.652
	I_Q04m	1.078	.033	.642
Calculating d. leisure*	H_Q03b	1.000	.000	.358
	H_Q03c	2.018	.078	.731
	H_Q03d	1.385	.066	.538
	H_Q03f	1.222	.056	.652
	H_Q03g	2.093	.091	.797
	H_Q03h	1.006	.048	.597
Calculating at work*	G_Q03b	1.000	.000	.460
	G_Q03c	1.782	.058	.802
	G_Q03d	1.505	.052	.679
	G_Q03f	1.090	.045	.620
	G_Q03g	1.724	.065	.799
	G_Q03h	.509	.024	.471
Literacy*	C1301C05S	1.000	0	.149
	C300C02S50	1.015	.138	.223
	D302C02S9	1.973	.259	.239
	D311701S8	2.099	.353	.277
	C3081207S	5.893	.754	.544

E3210061S	5.181	.692	.464
E3210502S	4.773	.677	.395
C3054215S	6.745	.819	.540
C3035218S	7.312	.888	.540
C3208117S	4.892	.606	.470
C1308119S	5.686	.719	.430
C308121S40	7.215	.871	.565
C308118S9	6.727	.824	.497
D304710S8	9.717	1.139	.717
D3047117S	5.286	.680	.389
D3155162S	5.744	.722	.425
E3270501S	6.917	.879	.527
E3274002S	6.152	.818	.454
E3237003S	6.181	.817	.462
E3227004S	4.916	.679	.413
C1308116S	5.827	.780	.445
C309320S30	6.785	.901	.548
C309321S9	3.657	.547	.409
D307401S8	2.305	.366	.357
D307402S7	7.696	1.001	.577
C3134126S	5.892	.837	.450

C3134154S	7.160	.942	.551
C3093419S	7.575	.925	.572
C3093322S	4.737	.650	.365
E3232001S	6.522	.821	.484
E3222002S	5.019	.653	.428
E1322005S	6.418	.790	.548
E320001S20	8.873	1.094	.677
E320003S9	7.803	1.004	.584
E320004S8	8.255	1.044	.613
C310406S7	7.902	.949	.635
C310407S6	7.757	.953	.563
E322003S5	6.698	.833	.517
E323003S4	9.009	1.119	.675
E323004S3	6.990	.932	.539
E322004S2	7.480	.956	.561
D306110S1	4.611	.574	.522
D306111S0	4.653	.637	.371
C313410S9	7.993	.972	.585
C313411S8	8.167	.991	.598
C3134137S	7.357	.906	.552
E3180061S	8.245	1.047	.616

	E3180503S	8.336	1.068	.595
	E3234002S	5.532	.774	.462
	E3233005S	4.286	.651	.392
	E3229002S	5.743	.831	.426
	E1329003S	3.554	.545	.382
Numeracy	C600C04S	1.000	.000	.241
	C601C06S	1.032	.127	.198
	E645001S	2.814	.256	.342
	C615602S	2.427	.315	.316
	C615603S	3.968	.400	.473
	C624619S	2.928	.346	.360
	C624620S	5.463	.543	.496
	C604505S	3.338	.306	.435
	C605506S	3.901	.358	.440
	C605507S	3.980	.351	.491
	C605508S	3.272	.301	.436
	E650001S	4.847	.424	.500
	C623616S	4.754	.413	.502
	C623617S	7.056	.575	.653
	C619609S	5.796	.496	.538
	E657001S	4.119	.403	.369

E646002S	5.047	.472	.543
C620610S	5.446	.493	.587
C620612S	4.133	.483	.369
E632001S	3.869	.456	.359
E632002S	4.590	.463	.469
C2607510S	4.595	.518	.479
C6314601S	1.726	.338	.238
C6148607S	3.134	.393	.407
C6185608S	5.319	.607	.482
E6350601S	2.315	.293	.408
C6135270S	4.904	.554	.474
C6085138S	3.037	.377	.288
E655001S9	5.088	.450	.562
C602501S30	1.343	.200	.223
C1602502S	3.484	.365	.381
C6202503S	5.633	.503	.554
C6131516S	4.492	.501	.454
C6114517S	5.420	.589	.484
C6065509S	5.573	.551	.553
E6650061S	4.385	.396	.511
E6650027S	5.809	.524	.523

	C622615S8	5.486	.503	.491
	E636001S9	5.697	.575	.523
	C617605S40	5.937	.597	.536
	C1617606S	5.086	.557	.469
	E6241001S	5.786	.522	.509
	E6631001S	7.204	.603	.641
	E6614002S	6.661	.578	.578
	E6600503S	5.551	.500	.509
	E6600064S	4.345	.445	.383
	E6340017S	5.180	.549	.484
	E634002S8	7.388	.684	.626
	E651002S9	7.849	.710	.657
	E664001S50	7.189	.669	.612
	E1644002S	7.428	.686	.628
	C6212518S	4.080	.481	.415
PS-TRE	U011a000S	.884	.030	.699
	U01b24000S	.326	.012	.653
	U02x03500S	.685	.027	.629
	U03a0040S	.313	.012	.631
	U04a0005S	.602	.030	.516
	U06a000S6	.207	.012	.467

U06b000S7	.227	.013	.457
U07x000S8	.260	.013	.520
U11b000S9	.666	.033	.528
U16x000S10	.286	.012	.586
U1119a000S	.265	.011	.609
U129b000S	.603	.021	.692
U213x000S	.302	.013	.605
U23x4000S	.950	.052	.582

Note: *=modified model (for modifications see section results), d. leisure= during leisure Item= item code, *estimate*= unstandardized path coefficient, *std.err*= standard error, *std.all*=standardized path coefficient, *PS-TRE*= Problem solving in a technology-rich environment.

Running Head: READING AND ENVIRONMENTAL ENRICHMENT

How Openness enriches the environment: Read more!

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Abstract

The recently proposed OFCI model and specifically the Environmental Enrichment Hypothesis state that Openness positively influences the development of cognitive abilities (Ziegler, Danay, Heene, Asendorpf, & Bühner, 2012). It is assumed that Openness leads to engagement in more learning activities through creating an enriched environment (e.g. reading). However, despite positive evaluations of the OFCI model in general, there is little empirical research on this specific hypothesis. The current paper used a longitudinal design to test the positive impact of Openness on the frequency of reading activities in general and in the specific case of periods of unemployment. PIAAC (Programme for the International Assessment of Adult Competencies) data were used to fit structural equation models. The results show that Openness fosters greater engagement in reading activities over 3 years; a buffering function in case of unemployment could not be found. Theoretical and practical implications are discussed.

Keywords: OFCI model, Environmental Enrichment Hypothesis, Reading, PIAAC Germany, PIAAC-L

The current work builds on the Openness-Fluid-Crystallized-Intelligence model (OFCI model; Ziegler, Danay, Heene, Asendorpf, & Bühner, 2012) and the Environmental Enrichment Hypothesis included therein. According to this hypothesis, Openness is assumed to have a positive impact on the development of cognitive abilities. It is hypothesized that higher Openness leads to more learning opportunities by fostering an enriched environment (e.g. by reading). Furthermore, it is assumed that the effect is especially strong in early and late adulthood, because these time periods are characterized by changes (life events like starting one's first job or retirement) that allow differences in Openness to manifest, facilitating the creation of more learning opportunities. While numerous studies support the notion of developmental relations between Openness and cognitive abilities (Baker & Bichsel, 2006; Furnham & Cheng, 2016; Trapp, Blömecke, & Ziegler, 2019; Von Stumm & Deary, 2012; Wettstein, Tauber, Kuźma, & Wahl, 2017; Zhang & Ziegler, 2015; Ziegler, Cengia, Mussel, & Gerstorf, 2015; Ziegler et al., 2012; but also see: Hülür, Gasimova, Robitzsch, & Wilhelm, 2018; Von Stumm & Deary, 2013), the concrete assumptions of the Environmental Enrichment Hypothesis have rarely been explored. This includes the idea that Openness manifests in activities (e.g. reading) that serve as learning opportunities and in this way enhances cognitive abilities. Moreover, the notion of critical time periods influencing the manifestation of Openness (Ziegler et al., 2012) has also only been tested indirectly. The current study was conducted to fill these gaps.

Environmental Enrichment Hypothesis

The Environmental Enrichment Hypothesis can be traced back to ideas by Raine, Reynolds, Venables, and Mednick (2002) and Neisser et al. (1996). In their study of children's cognitive development, Raine et al. (2002) showed that higher curiosity as manifested in stimulation-seeking behavior among 3-year-old children goes along with higher cognitive ability at age 11. Earlier, Neisser et al. (1996) had used the term "environmental enriching" to describe the effects of educationally enriched environments on children's intelligence. Thus, Raine et al. (2002) called the effect found in their study the Environmental Enrichment Hypothesis. They assumed that children create an enriched, stimulating, varied, and challenging environment for themselves by seeking stimulation. This enriched environment is hypothesized to enhance cognitive development. Hence, behaviors like physical exploration of the environment, social engagement with other children, and verbal interaction with adults are thought to enhance young children's cognitive development.

In 2012, Ziegler et al. introduced the Openness-Fluid-Crystallized-Intelligence model (OFCI model). They proposed that relationships between Openness and crystallized (gc) and fluid intelligence (gf) affect not only immediate performance but also cognitive development. The Environmental Enrichment, Environmental Success and Mediation Hypotheses are probably the most important assumptions in the developmental part of the model: The Environmental Enrichment Hypothesis mirrors Raine et al.'s proposal described above. The Mediation Hypothesis further assumes that this positive effect of

Openness on fluid intelligence also positively affects the development of crystallized intelligence. The Environmental Success Hypothesis assumes that intelligence positively influences the development of Openness.

In their Environmental Enrichment Hypothesis, Ziegler and colleagues generalized the effect found by Raine et al. to adults and the personality trait Openness. Openness is defined as the general willingness to engage with new stimuli, and thus provides a starting point for learning. However, dealing with complex new situations requires Gf. Thus, Openness only leads to learning, and thus the acquisition of Gc, indirectly through mastering complex new information. This mastery is influenced by Gf, which explains why Openness is presumed to be related to both cognitive abilities.

When transferring the Environmental Enrichment Hypothesis into adult life, Ziegler et al. (2012) assumed Openness to be associated with activities that enrich adults ’lives, e.g. “visits to museums, exhibitions, and concerts, or some kind of actual artistic engagement” (p.180). Trapp, Blömecke, and Ziegler (2019) provided first empirical evidence supporting the Environemntal Enrichment Hypothesis in adults. In their study, they considered the activity aspect of the Environmental Enrichment Hypothesis by proposing that mental activities like reading and calculating are important environment-enriching activities. Their results showed that reading and calculating at work and during leisure time do in fact make important contributions to environmental enrichment. These findings suggest that enrichment can take the form of cognitively stimulating content. Furthermore, the study showed that reading professional journals or publications at work and reading diagrams, maps or

schematics during one's leisure time are especially related to Gf. Thus, enrichment does not necessarily have to involve real-life encounters. For adults, it might even be more realistic to assume that mentally enriching one's environment through reading occurs more often than actually experiencing new situations in real life. Unfortunately, the study by Trapp, Blömeke, and Ziegler did not use longitudinal data, making causal inferences impossible. The current study aims to overcome this deficit and focuses on reading as a means of enriching one's environment.

Spelling out the Environmental Enrichment Hypothesis: Reading Activities

The aim of the current study is to find support for the idea of reading as an important activity behind environmental enrichment. Prior studies (Kraaykamp and Van Eijck, 2005; Trapp et al., 2019) have demonstrated associations between Openness and reading activities. For example, Kraaykamp and Van Eijck (2005) investigated the influence of Big Five personality domains on media preferences and cultural participation in a Dutch sample that included people aged 18 to 70 (waves 1998 to 2000 of the Family Survey of the Dutch Population, N=3156). In regression analyses, they found Openness to be a predictor of reading as a preferred leisure activity.

Mussel (2013) could show that Openness strongly overlaps with or even includes traits like typical intellectual engagement (Arteche, Chamorro-Premuzic, Ackerman, & Furnham, 2009; Wilhelm, Schulze, Schmiedek, & Süß, 2003), of which reading is an important facet.

As mentioned above, Trapp et al. (2019) showed that reading and calculating at work and during leisure time are important activities behind environmental enrichment. In their study, they used cross-sectional PIAAC data, which include proxies for (a) Openness, (b) Gf, (c) indicators for Gc, and (d) information about the amount of reading and calculating activities conducted at work and during leisure time. The results of structural equation models illustrated that both reading and calculating activities mediated the relation between Openness and Gf and thus also the indirect influence of Openness on Gc (via a mediation by Gf).

In summary, the current study is based on the idea that Openness initiates learning processes that foster Gf and Gc. Thereby, Openness manifests in activities during work or leisure time that enrich a person's environment. In particular, the current study focuses on reading during leisure time as one example of such activities. Whereas prior research has established that Openness has an influence on a preference for reading (Kraaykamp and Van Eijck, 2005) or a cross-sectional mediation with Gf as an outcome, research focusing on actual reading activities utlizing longitudinal data is lacking. Thus, this developmental interplay between Openness and reading activities is one critical aspect of the current work.

Environmental Enrichment, Reading, and Unemployment

The previous sections described our general ideas about the role of reading in environmental enrichment. In addition to this general perspective, the interplay of Openness and reading can also be viewed in a more specific context.

Specifically, we focus on critical time periods as another hypothesis of the OFCI.

The OFCI model assumes that differences in Openness are more likely to matter in critical time periods. This assumption is based on trait activation theory (Tett & Burnett, 2003; Ziegler et al., 2014), which states that situational variables influence the manifestation of traits and thus their correlations with other variables. Accordingly, the effects of Openness on Gf and Gc should be especially strong in early and late adulthood, periods in which many changes occur (e.g. starting one's first job or ending a job, starting a family or losing one's partner). Such life events open up a multitude of options for each person, increasing the opportunity for differences in Openness to manifest. Alternatively, it can also be assumed based on trait activation theory that situational blockers (e.g., a strict work schedule) decrease the likelihood of trait manifestations.

Consequently, the effect of environmental enrichment should be especially strong in periods of life where many changes occur (e.g. starting one's first job or ending a job, starting a family or losing one's partner). Losing one's job is one such major individual life experience (Boyce, Wood, Daly, & Sedikides, 2015; Specht, Egloff, & Schmukle, 2011) that is associated with negative effects, for example on mental health (Creed & Evans, 2002; Murphy & Athanasou, 1999). Jahoda's (1982) latent deprivation model explains this negative impact as being due to the loss of latent functions of work, like the imposition of a time structure, regular social contact, and regularly enforced activity.

Creed and Evans (2002) noticed that personality also seems to play an important role in the context of unemployment. They referred to studies showing that some people did not suffer psychologically from being unemployed (Fryer & McKenna, 1987, Hesketh, Shoukssmith & Kang, 1987). Creed and Evans stated that these individuals "have found functional alternatives to accessing the latent functions in order to satisfy their basic psychological needs" (p. 1046). As one example, they named "continuing the pursuit of purposeful activity" (p.1046). Reading can be seen as such a meaningful leisure activity because it is associated with obtaining new information or new ideas which can help one master one's new situation after job loss. In addition, literature can be used to learn something new in order to increase one's chances of getting a new job. Consequently, reading could be a functional alternative to working during periods of unemployment. On the other hand, reading as a solitary activity cannot replace social contact as a latent function of work. However, Waters and Moore (2002) found that activities associated with positive coping responses during unemployment 1) must be meaningful, but 2) can be either solitary or social. In their study, they investigated the role of meaningful leisure activities in a sample of unemployed (N=201) and employed (N=128) Australians. Their findings showed that both solitary and social activities were negatively related to most indicators of deprivation (time structure, shared experience, personal identity, purpose, enforced activity). Consequently, reading can be seen as an important and helpful activity for people who are unemployed. By providing new information and ideas, reading fosters environmental enrichment during unemployment, so that people might not psychologically suffer from

deprivation. Thus, reading might help individuals cope with the negative effects of unemployment.

With regard to unemployment per se, a study by Viinikainen and Kokko (2012) showed that Openness predicted a higher number of unemployment spells during life, but had no effect on the duration of each individual unemployment spell. Viinikainen and Kokko (2012) stated that "a higher level of Openness might cause individuals to seek out new experience and new challenges, and this would lead to breaks in an individual's working career" (p. 1214). Thus, more open people might see job change as an opportunity rather than a loss and use the period of unemployment more positively. Findings by Roberts, Caspi, and Moffitt (2003) fit in with this bigger picture by showing that Openness decreases with longer durations of unemployment. This means that Openness is associated with unemployment in two ways. On the one hand, open people seem to be more open to job changes and unemployment. On the other hand, Openness decreases after a longer period of unemployment. The OFCI perspective might provide an explanation for the latter effect, as Openness differences are considered more likely to manifest in critical time periods, including prolonged unemployment. As hypothesized above, reading could be one such manifestation that also acts as a protective factor against the negative effects of unemployment.

In conclusion, some specific hypotheses can be derived from the proposed Environmental Enrichment Hypothesis model. Job loss can be seen as a critical life event. This change can go along with more learning opportunities due to more available time, meaning that Openness could manifest in

environmentally-enriching activities like reading. Thus, higher Openness should be associated with more reading activities. However, at the same time, job loss in general reduces all activities due to latent deprivation. Hence, the general trend is towards reduced reading activity. In summary, this means job loss should tend to reduce reading activities, but this trend could be buffered by higher Openness.

Aims of the Study

In accordance with the OFCI model's Environmental Enrichment Hypothesis, Trapp et al. (2019) showed that reading activities at work and during leisure time mediate the influence of Openness on cognitive abilities. They used the first wave of PIAAC data to test this assumption in a cross-sectional design. The follow-up waves of PIAAC provide an opportunity to investigate the role of reading in the Environmental Enrichment Hypothesis in a longitudinal design. Hence, the current study aims to replicate the findings by Trapp et al. (2019) in a longitudinal design using PIAAC data from 2012, 2014, and 2015 by examining the role of reading activities with regard to environmental enrichment. Because there are only three measurement occasions, the developmental interplay between only two variables can be investigated. Thus, this study will focus only on Openness and its impact on reading during leisure time. Our assumptions with respect to this first research aim are as follows: First, we assume that Openness and reading activities are related cross-sectionally (Hypothesis 1). Second, we assume that Openness will have a longitudinal positive influence on reading activities (Hypothesis 2).

The current study also seeks to examine this effect in the specific context of unemployment. This will test a further hypothesis of the OFCI model. The idea behind this hypothesis is that the relation between Openness and reading activities should be stronger during unemployment due to trait activation. Losing one's job is generally not seen as a chance to learn something new, but is characterized by symptoms of depression and a general decrease in activities. However, based on the fact that some people do not follow this general trend and do not suffer after a job loss, as well as the idea that meaningful solitary leisure activities (e.g. reading) can be helpful for coping, we hypothesized as follows: first, job loss has a negative effect on reading activities. In other words, reading should decline after job loss, but not among people who remain employed (Hypothesis 3). On the other hand, we propose that this decline in reading after job loss will be buffered among people higher in Openness. Thus, we assume a buffering effect of Openness on this decline in reading activities (Hypothesis 4).

Methods

Sample and Procedure

The current study is based on a secondary analysis of previously published and publicly available data: The German sample of the Programme for the International Assessment of Adult Competencies (PIAAC, Rammstedt, 2013; Zabal et al., 2014; Zabal, Martin, & Rammstedt, 2016). PIAAC was initiated by the Organization for Economic Cooperation and Development (OECD). In Germany, it was conducted by GESIS – the Leibniz Institute for Social Science. The program started in 2012 with the goal of investigating adults ʾcompetencies. Other factors that might influence the development of such competencies were also examined, such as personality and use of skills like reading as well as information about professional activities. In 2014, a national follow-up study in Germany began. The current study used data from three waves: 2012, 2014, and 2015.

In 2011/2012, PIAAC compared the job-specific competencies of adults in different countries. In Germany, 5465 adults aged 16 to 65 years took part. The sample was collected using information provided by the municipalities and registry data (Zabal et al., 2014). In 2014, PIAAC anchor persons and their household members were targets of the survey. The sample size here was 7938 participants, out of which 3758 subjects had also been tested in 2012 (Zabal et al., 2016). In the following wave in 2015, anchor persons and their partners were of interest. Here, 4631 people were tested, of whom 3263 had also been tested

in 2012 and 2014 (Zabal et al., 2016). In the current study, only data from PIAAC participants who took part in the survey in 2012, 2014 and 2015 were used. Thus, the final sample size used in this study was *N*=3263.

In the second part of the current study, only a subsample of these participants were used. We focused on people who had experienced a job loss between 2012 and 2014 and compared them to those who did not experience unemployment in that timespan. Therefore, two groups were built. The first group (*job loss* group) included all people who stated that they were employed full-time (*N* = 120) or part-time (*N* = 71) in 2012 and were currently unemployed in 2014 (*N* = 191). The 85 males and 106 females in this group were between 16 and 65 years of age (*M* = 44, *SD* = 14.96). The second group (*job continuation* group) consisted of all people who stated that they were employed in 2012 as well as in 2014 (*N* = 1831). This group included 981 males and 850 females. Their ages ranged between 19 and 65 years (*M* = 43, *SD* = 10.37).

Data collection for all survey waves was conducted in participants ' homes. Trained interviewers led a personal standardized interview. In the first wave, this also included a background questionnaire (Allen et al., 2013), followed by further computer assessments not examined in the current paper. The current study focuses on data from the personal information questionnaire (e.g. personality and job status). In the last wave, instruments from the National Educational Panel Study (NEPS) were the main focus of the survey. Of these, only the assessment of reading activities was important for the purposes of this study. For more information about the Programme for the International Assessment of Adult Competencies, including information about the data

quality standards, see previously published reports about PIAAC (e.g. Rammstedt, 2013; Zabal et al., 2014; Zabal, Martin, & Rammstedt, 2016) as well as the project's website (http://www.gesis.org/en/en/piaac).

Measures

Openness measures

The PIAAC background questionnaire in 2012 included questions about typical habits for dealing with problems and tasks, focusing on the newness of the information. The items were rated on a scale from 1 (*not at all*) to 5 (t*o a very high extent*). The instrument is called *learning strategies* and was used in this study as an indicator of Openness. All six items of the instrument can be found in Table 1.

In 2014, a questionnaire developed for the SOEP was used. This questionnaire included a short scale for the Big Five (Lang, John, Lüdtke, Schupp, & Wagner, 2011). Three items assessed Openness (*I see my self as someone who…:* (1) *values artistic/aesthetic experience*, (2) *has a vivid imagination, (3) is innovative, comes up with new ideas*). Participants had to answer using a rating scale from 1 (*Does not apply at all*) to 7 (*Applies completely*).

It should be noted that we used a scale called *learning strategies* as the Openness measure in 2012. In the second measurement occasion, Openness was measured using the BFI-S (Lang et al., 2011). Unlike the learning strategies scale, which focuses on the intellectual aspect of Openness, the three Openness items in the BFI-S stress the cultural aspect of Openness. This should reduce the autoregressive correlation between the two Openness measures.

Measures for reading activities during leisure time

The background questionnaire for PIAAC Germany 2012 (Allen et al., 2013) included questions about reading during leisure time. The six items concern different sources of information. In the current study, books and newspapers were selected as sources of information because these are the only items measured at both occasions. All questions were answered with regard to frequency (1 = *never*, 2 = *less than once a month*, 3 = *more than once a month and less than once a week*, 4 = *more than once a week, but not daily*, 5 = *daily*).

The 2015 questionnaire included two questions about reading activities during leisure time referring to books/e-books and newspapers (including online newspapers). Both questions were answered on a 5-point frequency scale (1 = *daily*, 2 = *at least once a week*, 3 = *at least once a month*, 4 = *less frequently*, 5 = *never*, for analysis the scale was recoded, so 1 = *never* and 5 = *daily*).

Information about job status

The background questionnaire for PIAAC 2012 (Allen et al., 2013) included a section with job-related questions. One question asked participants to choose from the following list of statements which one best describes their current situation: (1) employed full-time, (2) employed part-time, (3) unemployed, (4) pupil or student, (5) completing an apprenticeship or internship, (6) retired or in early retirement, (7) permanently disabled, (8) in compulsory military or community service, (9) fulfilling domestic tasks or looking after children/family, or (10) other.

In PIAAC 2014, an adapted version of the SOEP personal questionnaire was used. The following two questions were asked regarding job status: “Are

you currently employed? Which one of the following applies best to your status? Retirees or individuals in the federal volunteer service ('Bundesfreiwilligendienst') who also work in addition to this, please state your job here". Persons could answer that they were (1) employed full-time, (2) employed part-time, (3) in vocational training, (4) marginally employed, (5) in partial retirement with zero working hours, (6) in voluntary military service, (7) completing a voluntary social/ecological year or federal voluntary service, (8) in a sheltered workshop, or (9) not employed.

Statistical Analyses

All analyses and data preparation procedures were implemented using R (R Core Team, 2014). In a first step, the data sets for 2012, 2014, and 2015 were merged. Only persons with data in all three measurement occasions were included ($N = 3263$).

Descriptive statistics were calculated using the R package psych (Revelle, 2014). For easier interpretation, the scale concerning reading habits at the second measurement occasion was reverse coded. Construct reliability McDonald's Ωw was calculated using the R package horst (Horstmann, 2016).

The main analyses were based on testing structural equation models. For these analyses, the R package lavaan 0.5-16 (Rosseel, 2014) was used. Guidelines by Hu and Bentler (1999) for the Comparative Fit Index *(*CFI $\approx .95$), the Standardized Root Mean Square Residual (SRMR $\leq .09$) and the Root Mean Squared Error of Approximation (RMSEA $\leq .06$) were used to evaluate model fits. In addition, the recommendations of Heene, Hilbert, Draxler, Ziegler, and

Bühner (2011) were applied. Before constructing structural equation models, measurement models for both indicators of Opennness were tested. Measurement invariance between groups was tested according to Chen (2007) recommendations.

Next, correlations between the indicators of Openness and reading activities were estimated. Correlations were considered between reading activities, i.e. reading books/reading newspapers, and Openness measured as (1) a manifest variable using the mean scores of the variables, and (2) a latent variable within a structural equation model. Which reading activities were included into the following structural equation models depended on their relation with the Openness indicator.

In order to examine the interplay between Openness and reading activities over time, a cross-lagged model was specified (*Model Development*). As can be seen in Figure 1, four important paths were included. First, an autoregressive correlation between the indicators of Openness was specified, representing the development of that trait from 2012 to 2014. The same was done for a manifest reading variable (reading books or reading newspapers). Then, two cross-lagged paths were added to demonstrate the impact of reading on Openness and vice versa. Based on our hypotheses, it was expected that the indicators of Openness and reading would correlate positively within each measurement occasion (Hypothesis 1). This will be tested using the bivariate correlations. Moreover, the Openness indicator at time point 1 was expected to have a positive effect on reading at time point 2 (Hypothesis 2), which was tested with the cross-lagged model just described.

Afterwards, the impact of Openness on reading after job loss was considered. To this end, two groups (*job loss* vs. *job continuation*) were compared using a multigroup latent change score model[2] (McArdle, Grimm, Hamagami, Bowles, & Meredith, 2009). Figure 2 displays the Model *Job Loss*. As can be seen, the Openness indicator and both reading measures were modeled as latent variables. The Openness indicator had six items (see Table 1). To create latent variables for the reading measures, the residual variances of the two respective manifest variables were fixed to one minus the commonality of the respective item. These commonalities were derived from a principal component analysis extracting one factor from all reading items. This item communality can be considered a lower bound estimate of the reliable variance. Thus, the difference between one and this communality can be considered an estimate of the unreliable variance (for an example see Hoppe, Toker, Schachler, & Ziegler, 2017). This estimate was $1\text{-}h^2 = .75$ for reading books and $1\text{-}h^2 = .61$ for reading newspapers. Next, an autoregressive correlation between the latent variables for the reading measures was added with a fixed regression weight of 1. The residual variance was fixed to zero. Then, the latent change score *delta* for reading was defined using reading 2015 with a fixed loading of 1. Thus, this latent change score includes all reliable differences between the two measurement occassions. To confirm Hypothesis 3, a paired *t*-test was conducted. To estimate baseline effects, reading 2012 was used to predict delta. Importantly, the influence of Openness on this change was estimated by regressing the change score onto the latent variable for the Openness indicator. According to Hypothesis 4, a positive

[2] Thanks to an anonymous reviewer for this suggestion.

influence of Openness on the change in reading was expected, which would reflect a buffering effect.

In order to test for group differences with regard to the path from Opennss to the change score, a second model was specified and compared. Within this model, the path was restricted to be equal across both groups. Model comparison was based on the difference in CFI, with changes less than $\Delta CFI \leq .002$ indicating no group differences (Meade, Johnson, & Braddy, 2008). These results would falsify Hypothesis 4.

Results

Descriptive Statistics and Measurement Models

Descriptive statistics for all variables used in the study to build the measurement and structural models are displayed in Table 2. Tables 4 - 6 show the intercorrelations of these variables for the subsamples. Here, it can be seen that the sum score of the Openness indicator items was significantly correlated with reading books and newspapers in 2012. In 2015, the correlation with reading newspapers was no longer significant. Thus, Hypothesis 1 was supported with this one exception.

The measurement model for the Openness indicator on the first measurement occasion was tested in the general sample as well as in the *job loss* and *job continuation* groups. In all cases, the model was acceptable after adding correlated residuals (see Table 3) between two items that share an analyzing aspect (*to get the bottom of difficult things* and *to figure out how different things fit together*). The model was measurement invariant (configural and metric) for the groups *job loss* and *job continuation (see Table 3)*. The six items had correlations between $r = .28$ and $r = .59$ in the general sample, between $r = .21$ and $r = .58$ in the *job loss* group, and between $r = .26$ and $r = .58$ in the *job continuation* group (see also Tables 4, 5, and 6). Construct reliabilities for these final models were $\Omega_w = .81$ in the general sample and $\Omega_w = .81$ the *job loss* and *job continuation* groups.

In the second measurement occasion, the Openness items from the BFI-S were used. Because this instrument had only three items measuring Openness, the measurement model can only be specified and model fit cannot be estimated. The item loadings onto the latent variable were λ = .42 (*values artistic experience*), λ = .66 (*vivid imagination*), and λ = .61 (*inventive, full of ideas*). Construct reliability was Ω_w = .61 in the general sample (group *job loss:* Ω_w = .67, group *job continuation:* Ω_w = .63).

Reading newspaper and reading books were correlated with r = .19 (*job loss* group: r = .34, *job continuation* group: r =.16, all $p < .001$) in 2012 and with r = .12 (*job loss* group: r = .10, *job continuation* group: r =.09, all $p < .001$) in 2015. The low correlation was the reason why no common latent variable was built with these two variables as indicators. Instead, reading books and reading news were analyzed separately.

The autocorrelations across time were positive. The mean scores of the two indicators of Openness were correlated with r = .32 ($p < .001$), and the latent correlation was r = .49 ($p < .001$). Reading books in 2012 and 2015 were correlated with r = .61 ($p < .001$). For reading newspapers, the correlation was r = .32 ($p < .001$). The correlations between constructs and across time were r = .20 ($p < .001$) for the 2012 Openness indicator and reading books in 2015, and r = .16 ($p < .001$) for reading books in 2012 and the Openness indicator in 2014 (see also Table 4). For reading newspapers, the correlation with the Openness indicator at the first time point was r = .14 ($p < .001$, see also Table 4). Both cross-lagged correlations were r = .06 ($p < .001$, see also Table 4). However, reading newspapers and Openness were not correlated at the second

measurement occasion. Thus, Hypothesis 1, which assumed that the Openness indicator and reading activities would be related at each time point, was mostly supported. The exception was reading newspapers, which was not related to Openness at the second measurement occasion. Therefore, the following analyses were only conducted with reading books.

Openness and Reading Activities Across Time

The cross-lagged-model including the Openness indicator and reading activities can be seen in Figure 1. The model fit was acceptable (see Table 3). The autoregressive effect for the Openness indicator was $\lambda = .48$ ($p < .001$). For reading, the autoregressive effect was $\lambda = .60$. The latent correlation between the Openness indicator and reading at time point 1 was $r = .30$ ($p < .001$). The residuals for the second occasion were not related ($r = -.01$, n.s.)[3]. The impact of the 2012 Openness indicator on reading books in 2015 was $\lambda = .16$ ($p < .001$). However, reading in 2012 had no influence on the Openness indicator at the later time point ($\lambda = .03$, *n.s.)*. Thus, Hypothesis 2 about the positive influence of the Openness indicator on reading at a later time point was supported.

Openness and Reading Activities after Job Loss

The second aim of the current paper was compare the influence of Openness on reading in two situations, after job loss vs. during continued employment. Hypothesis 3 assumed that reading declines after job loss, and

[3] Thanks to an anonymous reviewer for suggesting a model with *arts* and *ideas* as a single indicator for Openness at the second occasion. The results can be found in the supplemental material. Implications for our hypothesis stay the same regardless of the indicator of Openness used.

Hypothesis 4 that Openness buffers this decline. The effects are not predicted in the case of continued unemployment.

In the *job loss* group, the frequency of reading books at time point 1 had an average rating of $M = 3.18$ ($SD = 1.40$). At the second time point, the mean was hardly different, $M = 3.19$ ($SD = 1.48$, $t_{190} = -.103$, $p = .92$, *Cohen's d* = .007). In the *job continuation* group, reading rates decreased ($t_{1829} = 2.87$, $p < .005$, *Cohen's d* = .07) from $M = 3.10$ ($SD = 1.44$) to $M = 3.02$ ($SD = 1.45$). Thus, Hypothesis 3 could not be confirmed. Despite this lack of a mean level change, there could be differential changes, and thus variance in the amount of change, which might be predicted by Openness as stated in Hypothesis 4. This was investigated with a latent change score model (see Figure 2). For both groups, the model fit was acceptable (see Table 3). The change score delta had a significant variance of $\sigma^2 = .96$ ($p < .05$)[4] for people who lost their job. For those remained employed, the variance was negative. Thus, we added the constraint to fix the variance of this variable to 1. Thus, despite the lack of mean level change, there were substantial interindividual differences in how reading behavior changed in both groups. While some people read less, others read more. We had hypothesized that the Openness indicator might be related to such differential changes in the case of job loss. To test that hypothesis, we first examined a regression of the latent change score for reading on the Openness indicator in a multiple-group latent change score model in which the path was freely estimated. Model fit was acceptable (see Table 3). However, the path was not significant in either group (unstandardized solution: .98, p=.67, see also

[4] Standardized solution.

Figure 2). Next, this path was restricted to be equal. This model also fits well (see Table 3). The difference in CFI was below the set cut-off. Thus, assuming equal influence did not deteriorate model fit substantially. The path in this restricted model was (r = .008, n.s.). Thus, Hypothesis 4 could not be supported.

Discussion

The Environmental Enrichment Hypothesis of the OFCI model (Ziegler et al., 2012) states that the personality trait Openness increases people's likelihood of encountering new and cognitively stimulating situations, which positively affects the development of cognitive abilities. While the OFCI model in general as well as the Environmental Enrichment Hypothesis had been supported in several studies (Trapp, Blömeke, & Ziegler, 2019; Ziegler, Cengia, Mussel, & Gerstorf, 2015; Ziegler, Danay, Heene, Asendorpf, & Bühner, 2012), there was little examination of possible processes behind this effect. Trapp et al. (2019) found support for the idea that reading activities play an important role in environmental enrichment. In a cross-sectional design, they could show that reading activities at work and during leisure time mediated the impact of Openness on cognitive abilities. Thus, Openness manifests in reading activities, which enriches one's environment and thereby influences cognitive abilities. The current study sought to replicate the importance of reading activities in a longitudinal design. Therefore, PIAAC data were used to investigate the interplay of Openness and reading activities. In addition, the current study sought to test the idea that Environmental Enrichment is especially likely in times of change. To this end, the impact of Openness on changes in reading activities after job loss was examined. The current findings support the idea that

Openness affects reading behavior. However, no buffering effect of Openness on reduced reading activity in times of unemployment was found.

Relation between Openness and Reading Activities across Time

The Openness indicator in 2012 was related to reading books at the same time point as well as at a later time point. For reading newspapers, there were relations between the Openness indicator in 2012 and reading in 2012 and 2015, but not between the Openness indicator in 2014 with reading newspapers in 2015. These findings are not completely in line with the results by Trapp et al. (2019), where the Openness indicator was related to both reading books and reading newspapers. Thus, the effect could be replicated for reading books, but not for reading newspapers. It is hard to explain this failed replication based on the current data. However, given that the Environmental Enrichment Hypothesis assumes that Openness should lead a person to seek out new and most of all stimulating situations, the content of newspapers per se might not suffice. This might be different for periodicals or journals. Moreover, the addition of online newspapers to the item might also have had an impact. Such outlets are often consumed using handheld devices over short periods of time. Thus, longer contemplation of the content is not easily possible. The same cannot be said for reading e-books, which requires one to think about the content at least during the time of reading. Thus, future research should pay closer attention to the medium and potentially the situation in which it is used.

The current study adds to the literature by testing the longitudinal effect of Openness on reading activities. Together, this study as well as the study by Trapp et al. (2019) support the idea that reading provides environmental

enrichment: Greater Openness fosters willingness to engage in more reading activities at work and during leisure time. According to the OFCI model, more reading activities could serve as learning opportunities, which are assumed to foster the development of fluid intelligence directly and crystallized intelligence indirectly.

Environmental Enrichment after Job Loss

Besides this general effect of Environmental Enrichment, the OFCI model assumes that this effect changes in magnitude as a result of situational blockers and facilitators. During different life stages, certain life events can occur which act as situational moderators, creating critical time periods. More specifically, Ziegler et al. (2012) stated that the effect should be stronger in early and late adulthood because these life phases are accompanied by numerous changes, allowing differences in Openness to manifest. For example, these life phases are characterized by changes like starting one's first job/retirement or settling down and starting a family life/losing one's partner due to death. From the perspective of environmental enrichment, the environment after such a life change is a new one, offering opportunities to arrange one's environment in a completely new way. More open people are likely to seek out new situations and try completely new ways of handling the situation, while less open people may try to hold on to established ways.

Job loss is one such life event known to be associated with drastic changes (financial constraints and other effects described in Jahoda's (1981) latent deprivation theory). It is well known that job loss is associated with negative consequences for one's life (e.g. higher rate of depression, decreased

activities). Like most activities, we expected reading to decrease after job loss as well. Furthermore, we assumed that Openness would be crucial in this context with regard to reading as a meaningful leisure activity and expected the Openness indicator to buffer the decrease in activities like reading after job loss. However, our results revealed neither a decline in reading activity nor a buffering effect of Openness. The latter could be tested due to substantial interindividual differences in changes in reading activity.

Even if Openness does not buffer the decrease in reading activities after job loss, does not follow automatically that Openness cannot buffer negative effects of unemployment per se. We supposed that highly open people would see their new situation following a job loss as an opportunity and try out new ways of using their time. They could try out a new hobby or go on a long holiday. This might seem unlikely due to a lack of financial resources. However, there are people who work for only half a year and fill the other half with leisure activities financed by their work during the first half of the year. As these activities are not necessarily associated with more reading, but could also lead to less reading activity in some cases, changes in activities might not be reflected in changes in reading activities. Thus, future studies should include a wider array of Openness indicators.

Another potentially influential variable is the duration of unemployment. In fact, Specht et al. (2011) found a decrease in Openness after job loss depending on the duration of unemployment. They stated that changes in personality could be seen as adaption to one's new situation after a major life event (e.g. job loss). Perhaps Openness decreases with a longer period of

unemployment due to a lack of opportunities to manifest one's Openness (e.g. having no money to buy interesting books immediately). The current study examined people who were employed at time point 1 and not employed at time point 2, thus spanning a gap of two years. Unfortunately, the exact duration of unemployment is unknown. This means that some participants could have been unemployed for nearly two years, while others lost their jobs just one or a few months prior. If Openness is only effective for a short time after job loss, the people with longer durations of unemployment would have distorted the results.

Limitations

The current study has several advantages: First, a large sample with more than 3,000 people was used for the analyses of the general effect of Openness on reading. Second, a longitudinal design was utilized. Nevertheless, there are also several limitations that must be mentioned.

The first limitation is that Openness was measured differently across occasions: the *learning strategies* scale was used at the first measurement occasion and the BFI-S at the second measurement occasion. The two measures differ in focus. The *learning strategies* scale includes questions about habits in learning situations, thus stressing the intellect aspect of Openness, while the BFI-S includes three items emphasizing the cultural aspect (*values artistic experience*; *vivid imagination*; *inventive, full of ideas*). Thus, in the cross-lagged model used in the current study, the change in Openness over time also includes a change in method. This must be taken into consideration when interpreting the rather weak autoregressive path.

The second limitation is that reading books was used as a single indicator for reading behavior and that the exact phrasing of this item changed, as it also included electronic media at the second measurement occasion. Thus, as was the case for Openness, content validity might have changed. This along with the narrow scope of the reading items used reduces the measure's generalizability to reading in general. Thus, the results should be interpreted with this limitation in mind.

Conclusions

The current study can be seen as a further extension of the study by Trapp et al. (2019). In that paper, it was found that reading acted as a mediator between Openness and fluid intelligence. While this generally expanded our understanding of environmental enrichment, the cross-sectional nature of the data limited its generalizability. To ensure that reading is influenced by Openness, the current study considered two measurement points. Thus, the development of Openness and reading over time as well as cross-lagged influences were examined. The results supported the impact of Openness on the development of reading activities.

Moreover, the influence of life events was considered as a further component of the OFCI model. We expected that reading activity would decrease after job loss, whereas Openness would buffer this negative trend. We found that reading activities changing on the individual level. The buffering effect of Openness was not supported. As discussed before, we would not conclude that Openness has no buffering effect on reduced activities in general. We assume that (A) Openness manifests in activities other than reading after job

loss, (B) that the effect is only relevant for a certain time period after job loss (e.g. only in the first months), and (C) that individuals 'financial situation might prevent differences in Openness from manifesting.

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Tables and figures

Table 1

*Items of 2012 Openness measure (**"**learning strategies" in PIAAC background questionnaire).*

Nr.	Item text
O11	When I hear or read about new ideas, I try to relate them to real life situations to which they might apply.
O12	I like learning new things.
O13	When I come across something new, I try to relate it to what I already know.
O14	I like to get to the bottom of difficult things.
O15	I like to figure out how different ideas fit together.
O16	If I don't understand something, I look for additional information to make it clearer.

Note. O11- O16= openness items in 2012 as named in the models.

Table 2

Descriptive statistics in the general sample, the job loss group, and the job continuation group.

	Whole sample			*Job loss* group			*Job continuation* group		
	N	*Mean*	*SD*	*N*	*Mean*	*SD*	*N*	*Mean*	*SD*
Openness Measures									
O11	3259	3.16	.82	191	3.06	.79	1829	3.21	.79
O12	3263	3.92	.85	191	3.82	.90	1831	3.93	.80
O13	3251	3.59	.84	190	3.51	.88	1827	3.60	.82
O14	3263	3.46	.92	191	3.51	.96	1831	3.51	.87
O15	3254	3.43	.93	191	3.43	.98	1824	3.46	.89
O16	3263	4.05	.81	191	3.97	.86	1831	4.09	.74
O21	3248	4.46	1.90	189	4.35	1.94	1822	4.44	1.87
O22	3259	5.09	1.51	189	5.10	1.55	1830	5.00	1.51
O23	3257	4.92	1.33	191	4.75	1.50	1828	4.94	1.31
OS1	3240	3.60	.61						
OS2	3243	4.83	1.16						
Reading Measures									
L1B	3263	3.13	1.44	191	3.18	1.41	1831	3.10	1.44
L1N	3263	4.33	1.06	191	4.22	1.21	1831	4.38	1.04
L2B	3262	3.03	1.45	191	3.19	1.48	1830	3.02	1.45
L2N	3263	4.21	1.17	191	4.09	1.28	1831	4.34	1.10

Note. O11-O16= openness items in 2012 (see also Table 1), O21-O23= Openness items in 2014, L1B= reading books in 2012, L2B= reading

books in 2015, L1N= reading news in 2012, L2N=reading news in 2015, OS1= sum score for Openness in 2012, OS2= sum score for Openness in 2014.

Table 3

Model fits.

	Global model fit			Fit indices		
Construct	χ^2	*df*	*p*	CFI	RMSEA	SRMR
Measurement models						
Openness T1 in G (1)	409.83	9	<.001	.92	.12 (90%CI [.11, .13])	.04
Openness T1 in G (2)	105.58	7	<.001	.98	.07 (90%CI [.05, .08])	.02
Openness T1 in JL (1)	20.12	9	.02	.96	.08 (90%CI [.03, .13])	.03
Openness T1 in JL (2)	17.40	8	.03	.97	.08 (90%CI [.03, .13])	.04
Openness T1 in JC (1)	255.32	9	<.001	.91	.12 (90%CI [.11, .13])	.05
Openness T1 in JC (2)	137.17	8	<.001	.96	.09 (90%CI [.08, .10])	.04
Measurement invariance						
Openness T1 conf.	154.505	16	<.001	.954	.093 (90%CI [.080, .106])	.037
Openness T1 metric	157.829	21	<.001	.955	.080 (90%CI [.069, .092])	.039

Model *Job Loss* conf.	200.420	38	<.001	.961	.069 (90%CI [.056, .074])	.036
Model *Job Loss* metric	204.194	43	<.001	.962	.061 (90%CI [.053, .069])	.037
Single group analysis						
Model *Development*	381.18	38	<.001	.96	.05 (90%CI [.05, .06])	.04
Model *Job Loss JL*	33.48	19	.02	.96	.06 (90%CI [.02, .09])	.06
Model *Job Loss JC*	164.92	18	<.001	.96	.07 (90%CI [.06, .08])	.03
Group comparisons						
Model *Job Loss A*	207.49	44	<.001	.96	.06 (90%CI [.05, .07])	.04
Model *Job Loss B*	204.20	43	<.001	.96	.06 (90%CI [.05, .07])	.04

Note: *df*= degrees of freedom. χ^2= chi square value*, p*= probability value o*f* χ^2*, SRMR*= root mean square residual*, RMSEA*= root mean error of approximation with 90% confidence interval*, CFI*= comparative fit index, model *(1*)= model without modifications, model *(2*)= modified model (for modifications see section results), T1= at time point 1, T2= at time point 2, in G= general sample, in JL= in *job loss* group, JC= *job continuation* group, conf.= model with assumption of configural measurement invariance, metric= model with assumption of metric measurement invariance, model A= with assumption of equality, model B= free estimation of paths.

Table 4

Intercorrelations of variables in general sample.

	O11	O12	O13	O14	O15	O16	O21	O22	O23	L1B	L2B	L1N	L2N	OS1
O12	.41***													
O13	.42***	.41***												
O14	.31***	.42***	.28***											
015	.37***	.43***	.34***	.59***										
016	.29***	.45***	.32***	.44***	.46***									
021	.15***	.18***	.14***	.12***	.19***	.11***								
022	.14***	.2***	.11***	.15***	.22***	.15***	.28***							
O23	.16***	.24***	.12***	.24***	.27***	.17***	.26***	.40***						
L1B	.13***	.16***	.12***	.08***	.12***	.13***	.21***	.08***	.03					
L2B	.15***	.17***	.16***	.09***	.14***	.14***	.21***	.08***	.01	.61***				
L1N	.12***	.07***	.06***	.09***	.11***	.12***	.08***	.02	.03	.19***	.18***			
L2N	.07***	<.01	-.01	.06***	.07***	.05***	.04*	<.01	.03	.10***	.12***	.34***		
OS1	.60***	.74***	.65***	.73***	.77***	.70***	.21***	.23***	.29***	.17***	.20***	.14***	.06***	
OS2	.20***	.28***	.17***	.22***	.31***	.19***	.76***	.74***	.69***	.16***	.15***	.06***	.03	.32***

Note. O11-O16= openness items in 2012, O21-O23= Openness items in 2014, L1B= reading books in 2012, L2B= reading books in 2015, L1N= reading news in 2012, L2N= reading news in 2015, OS1= sum score for Openness in 2012, OS2= sum score for Openness in 2014.

** $p < .05$, *** $p < .001$*

Table 5

Intercorrelations of all variables in the job continuation *group*.

	O11	O12	O13	O14	O15	O16	O21	O22	O23	L1B	L2B	L1N
O12	.41***											
O13	.40***	.38***										
O14	.29***	.42***	.26***									
015	.33***	.39***	.32***	.59***								
016	.27***	.42***	.28***	.45***	.46***							
021	.16***	.17***	.15***	.12***	.19***	.11***						
022	.16***	.20***	.10***	.19***	.24***	.16***	.25***					
O23	.15***	.23***	.11***	.26***	.32***	.19***	.20***	.42***				
L1B	.09***	.14***	.12***	.06***	.12***	.09***	.19***	.07***	.01			
L2B	.14***	.15***	.16***	.06***	.13***	.11***	.21***	.08***	<.01	.66***		
L1N	.11***	.06***	.02	.05*	.08***	.12***	.07***	.01	.01	.16***	.13***	
L2N	.07***	-.01	<.01	.01	.04***	.04	<.01	.01	.01	.09***	.09***	.31***

Note. O11-O16= openness items in 2012, O21-O23, L1B= reading books in 2012, L2B= reading books in 2015, L1N= reading news in 2012, L2N= reading news in 2015.

** $p < .05$, *** $p < .001$*

Table 6

Intercorrelations of all variables in the job loss *group*.

	O11	O12	O13	O14	O15	O16	O21	O22	O23	L1B	L2B	L1N
O12	.32***											
O13	.34***	.35***										
O14	.31***	.46***	.23***									
015	.37***	.40***	.34***	.58***								
016	.21***	.34***	.29***	.46***	.43***							
021	.02***	.25***	.22***	.17*	.08	.18***						
022	.16*	.19***	.12	.15*	.14*	.06	.25***					
O23	.15*	.29***	.01	.29***	.21***	.16*	.32***	.44***				
L1B	.13	.11	.09	.08	.03	.18***	.18***	.05	.06			
L2B	.08	.13	.16*	.01	<.01	.06	.16*	.07	-.04	.53***		
L1N	.01	.03	.17*	.09	.07	.06	.13	.01	.02	.34***	.30***	
L2N	.07	-.02	.09	.02	-.05	-.02	.13	-.12	.07	.16*	.10	.30***

Note. O11-O16= openness items in 2012, O21-O23, L1B= reading books in 2012, L2B= reading books in 2015, L1N= reading news in 2012, L2N= reading news in 2015.

** $p < .05$, *** $p < .001$*

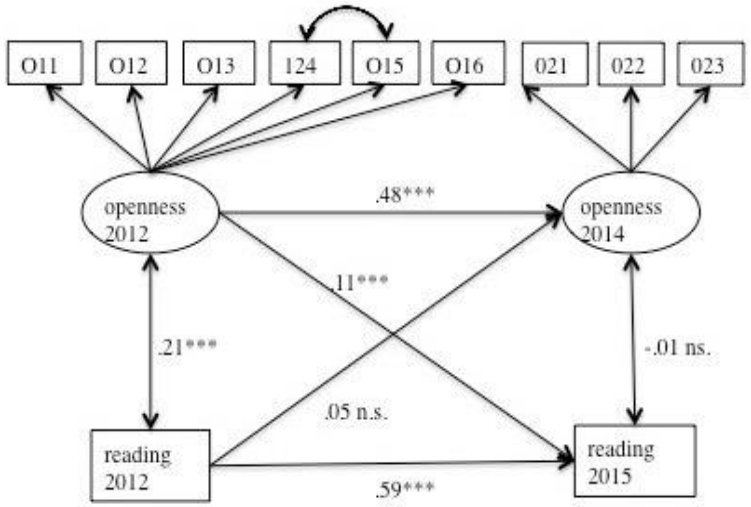

Figure 1: Cross-lagged model for Openness and reading books. Openness and reading books were measured two times each. The model includes autoregressive paths, the correlation path between openness and reading at the same measurement occasion, and cross-lagged paths between Openness and reading at different time points. Openness is a latent variable (loadings on the indicators were left out) and reading a manifest variable.
Note. O11-O16= indicators of Openness at the first measurement occasion (see also Table 1), O21-O23= indicators of Openness at the second measurement occasion.

*** $p < .001$

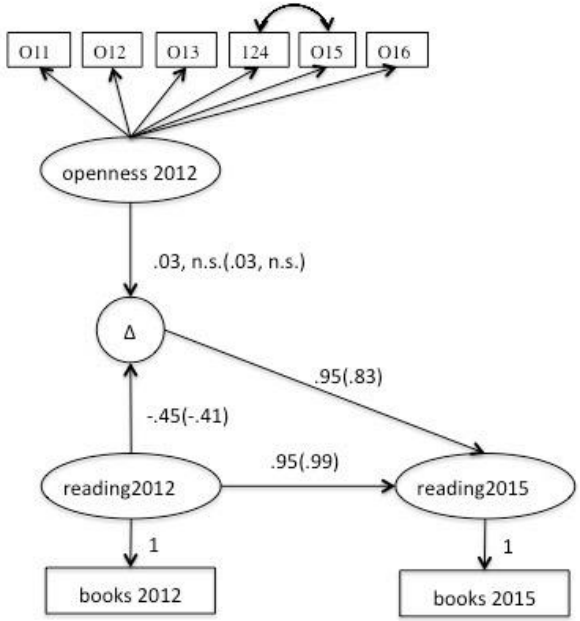

Figure 2: Latent change score model of latent change in reading and the influence of Openness. Δ= latent change in reading, O11-O26= items measuring openness in 2012 (loadings were left out). Non-standardized solution. Model including equal paths for groups.

Supplementary Material

Table A

Descriptive Statistics for Measurement Models

Construct	Item	*Estimate*	*SE*	*std.all*
Reading in leisure*	H_Q01a	1.000	.000	.512
	H_Q01b	.910	.038	.489
	H_Q01c	.684	.035	.378
	H_Q01d	1.235	.046	.593
	H_Q01e	.755	.044	.318
	H_Q01f	1.195	.043	.628
	H_Q01g	.420	.028	.262
	H_Q01h	1.196	.043	.619
Reading at work*	G_Q01a	1.000	.000	.477
	G_Q01b	1.824	.065	.746
	G_Q01c	1.735	.065	.731
	G_Q01d	1.433	.054	.720
	G_Q01e	.791	.038	.443
	G_Q01f	1.162	.046	.585
	G_Q01g	1.115	.052	.464
	G_Q01h	1.228	.051	.523
Openness*	I_Q04b	1.000	.000	.594
	I_Q04d	1.264	.034	.722
	I_Q04h	1.003	.030	.578
	I_Q04j	1.109	.036	.590
	I_Q04l	1.245	.037	.652
	I_Q04m	1.078	.033	.642
Calculating in leisure*	H_Q03b	1.000	.000	.358
	H_Q03c	2.018	.078	.731
	H_Q03d	1.385	.066	.538
	H_Q03f	1.222	.056	.652

	H_Q03g	2.093	.091	.797
	H_Q03h	1.006	.048	.597
Calculating at work*	G_Q03b	1.000	.000	.460
	G_Q03c	1.782	.058	.802
	G_Q03d	1.505	.052	.679
	G_Q03f	1.090	.045	.620
	G_Q03g	1.724	.065	.799
	G_Q03h	.509	.024	.471
Literacy*	E323004S	1.000	.000	.533
	C301C05S	.174	.022	.179
	C300C02S	.148	.016	.224
	D302C02S	.282	.029	.235
	D311701S	.298	.042	.271
	C308120S	.852	.076	.543
	E321001S	.738	.072	.456
	E321002S	.676	.073	.386
	C305215S	.966	.077	.534
	C305218S	1.044	.083	.533
	C308117S	.705	.059	.468
	C308119S	.806	.071	.421
	C308121S	1.041	.082	.563
	C308118S	.960	.078	.490
	D304710S	1.386	.101	.709
	D304711S	.754	.068	.383
	D315512S	.824	.071	.421
	E327001S	.987	.087	.520
	E327002S	.885	.085	.452
	E327003S	.889	.084	.459
	E327004S	.708	.073	.410
	C308116S	.826	.081	.436
	C309320S	.975	.095	.544

	C309321S	.525	.062	.405
	D307401S	.330	.043	.352
	D307402S	1.106	.103	.573
	C313412S	.836	.092	.441
	C313414S	1.040	.098	.553
	C309319S	1.082	.088	.564
	C309322S	.691	.070	.367
	E322001S	.940	.081	.482
	E322002S	.712	.067	.419
	E322005S	.932	.077	.550
	E320001S	1.277	.106	.675
	E320003S	1.122	.102	.580
	E320004S	1.180	.104	.607
	C310406S	1.138	.087	.633
	C310407S	1.117	.090	.561
	E322003S	.949	.079	.507
	E323003S	1.289	.104	.669
	E322004S	1.070	.094	.555
	D306110S	.660	.055	.517
	D306111S	.677	.068	.373
	C313410S	1.146	.091	.581
	C313411S	1.162	.091	.589
	C313413S	1.053	.086	.547
	E318001S	1.182	.105	.612
	E318003S	1.202	.109	.594
	E323002S	.793	.084	.457
	E323005S	.619	.075	.391
	E329002S	.822	.093	.421
	E329003S	.511	.063	.378
Numeracy	1C600C04S	1.000	.000	.241
	2C601C06S	1.032	.127	.198

3E645001S	2.814	.256	.342
4C615602S	2.427	.315	.316
5C615603S	3.968	.400	.473
6C624619S	2.928	.346	.360
7C624620S	5.463	.543	.496
8C604505S	3.338	.306	.435
9C605506S	3.901	.358	.440
10C605507S	3.980	.351	.491
11C605508S	3.272	.301	.436
12E650001S	4.847	.424	.500
13C623616S	4.754	.413	.502
14C623617S	7.056	.575	.653
15C619609S	5.796	.496	.538
16E657001S	4.119	.403	.369
17E646002S	5.047	.472	.543
8C620610S	5.446	.493	.587
9C620612S	4.133	.483	.369
20E632001S	3.869	.456	.359
1E632002S	4.590	.463	.469
C2607510S	4.595	.518	.479
C6314601S	1.726	.338	.238
C6148607S	3.134	.393	.407
C6185608S	5.319	.607	.482
E6350601S	2.315	.293	.408
C6135270S	4.904	.554	.474
C6085138S	3.037	.377	.288
E655001S9	5.088	.450	.562
C602501S30	1.343	.200	.223
C1602502S	3.484	.365	.381
C6202503S	5.633	.503	.554
C6131516S	4.492	.501	.454

	C6114517S	5.420	.589	.484
	C6065509S	5.573	.551	.553
	E6650061S	4.385	.396	.511
	E6650027S	5.809	.524	.523
	C622615S8	5.486	.503	.491
	E636001S9	5.697	.575	.523
	C617605S40	5.937	.597	.536
	C1617606S	5.086	.557	.469
	E6241001S	5.786	.522	.509
	E6631001S	7.204	.603	.641
	E6614002S	6.661	.578	.578
	E6600503S	5.551	.500	.509
	E6600064S	4.345	.445	.383
	E6340017S	5.180	.549	.484
	E634002S8	7.388	.684	.626
	E651002S9	7.849	.710	.657
	E664001S50	7.189	.669	.612
	E1644002S	7.428	.686	.628
	C6212518S	4.080	.481	.415
PS-TRE	U011a000S	.884	.030	.699
	U01b24000S	.326	.012	.653
	U02x03500S	.685	.027	.629
	U03a0040S	.313	.012	.631
	U04a0005S	.602	.030	.516
	U06a000S6	.207	.012	.467
	U06b000S7	.227	.013	.457
	U07x000S8	.260	.013	.520
	U11b000S9	.666	.033	.528
	U16x000S10	.286	.012	.586
	U1119a000S	.265	.011	.609
	U129b000S	.603	.021	.692

U213x000S	.302	.013	.605
U23x4000S	.950	.052	.582

Note. * = modified model (for modifications, see Results section), Item = item code, *estimate* = unstandardized path coefficient, *SE* = standard error, *std.all* = standardized path coefficient, *PS-TRE* = Problem solving in a technology-rich environment.

Summary of the Articles

Activities During Leisure Time and at Work Mediate the Positive Influence of Openness on Cognitive Development (Study 1)

Even Cattell (e.g. Cattell, 1987) proposed an influence of personality on the cognitive development in adulthood. Process models of adult intelligence such as those of Cattell (Cattell, 1987), Ackerman (Ackerman, 1996) and Ziegler (Ziegler et al., 2012) include an influence of personality traits, e.g. Openness. The Environmental Enrichment Hypothesis of the OFCI model gives an explanation for the effect. Thus, personality traits Openness would lead to learning situations, which train cognitive abilities (Ziegler et al., 2012). This study wants to validate this assumption by extending the model. Concretely, it is assumed that Openness would manifest in specific activities at work and during leisure time. These activities increase the likelihood of facing new situation and by that way foster cognitive development in adulthood. Thus, through increased engagement with those activities, Openness would have a positive impact on cognitive development.

To test this extended Environmental Enrichment Hypothesis of the OFCI model the Data on PIAAC panel were used. The panel data included more than 5,000 persons representative for German population. The data included an indicator of Openness, an indicator for Gf, and two indicators for Gc. Additionally, data of reading and calculating activities at work and during leisure time were available. Some models presenting the extended Environmental Enrichment Hypothesis were tested: Common to all models was Openness as a starting point. According to the assumption about the

manifestation in activities, the model assumes an influence of Openness on reading (models 1 and 2) and/or calculating activities (models 1 and 3). Since these activities act as moderators between Openness and Gf, a further path from the activities to Gf is assumed. In all models the same indicator is used for Gf. Finally, a path from Gf to Gc is assumed, which represents the Cattell's Investment Theory (Cattell, 1987). In the model with reading as activity a verbal ability is used as indicator for Gc. In the model with calculating as activity a numeric ability is used as indicator for Gc. In the general model both indicators are combined to one. In addition, a direct influence of Openness on Gc was included in all three models.

The results of all three models support the assumptions of the extended Environmental Hypothesis OFCI model. As in previous studies on intelligence development, the Investment Theory (an influence Gf on development of Gc, see above) could be confirmed. In addition, the positive influence of Openness on cognitive development (Environmental Enrichment Hypothesis of the OFCI model) was shown. More precisely, the extended assumption of mediation by reading and calculating activities (extended Environmental Enrichment Hypothesis) was confirmed.

To summarize, Study 1 looked at the structure of the relationships between core constructs of the Environmental Enrichment Hypothesis of the OFCI model and the extension by activities. However, these relations were tested cross-sectionally. Study 2 aims to build on this and explore the long-term nature of specific relationships.

The Longitudinal Perspective of Environmental Enrichment Hypothesis (Study 2. Part 1)

Some studies have already shown that Openness predicts intelligence at a later time (e.g. Wettstein et al., 2017; Ziegler et al., 2012) even if the influence of intelligence at an earlier time point is controlled for (Ziegler et al., 2015; Ziegler et al., 2012). This is in accordance with the main idea of the Environmental Enrichment Hypothesis of the OFCI model. This model proposes environmental enrichment as the explanation behind the positive influence of Openness on cognitive development. More precisely, the current work assumes that environmental enrichment is due to Openness's manifestation in fostering activities at work and during leisure time. Whereas a prior study supported the association of reading books with Openness and cognitive abilities, the recent one wants to support a longitudinal influence of Openness on these activities. Thus, Openness would be the drive behind positively influencing activities.

To do so, the long-term data of the PIAAC panel) was used in Study 2. Thus, again a very large sample of that panel data (see also Study 1) was available to study a longitudinal part of Environmental Enrichment Hypothesis. Data included an indicator of Openness and reading books as activities at work and during leisure for two time points each. A cross-lagged model was tested including an effect of Openness on reading at a later time point and reading on Openness at a later time point. Thereby, the effect was controlled for two sources of variance independent from a development effect. First, it was controlled for the direct effect within the same constructs at different time points

(autocorrelation). Second, the association between the two constructs at the same time point was modeled to control for this effect. So, Openness effect at the earlier time point the later time was also included as the same effect for reading at both time points as well as the associations of both constructs at the same time point.

Results could support a developmental effect of Openness on reading. This is accordance with the proposed extended Environmental Enrichment Hypothesis. Furthermore, a smaller developmental effect of reading on Openness could be found. Also that effect is congruent with OFCI model proposing an effect in opposite direction (Environmental Success Hypothesis). Both effects appear even under control of autocorrelation within the same construct as well as of association of both constructs at the same timepoint. Thus, there is an effect beyond.

The Longitudinal Perspective of Environmental Enrichment Hypothesis (Study 2. Part 2)

The Environmental Enrichment Hypothesis assumes that the positive effect of Openness on cognitive abilities can be generalized over all adult ages. However, is it also proposed that in specific ages the effect is stronger than in other age (Ziegler, et al. 2012). In OFCI model, the effect of age is traced back on the changes that particular occur in younger and older adult ages (Roberts et al., 2006). This critical timespans (typically more changes) would help Openness to be activated in situations because the likelihood of learning situations it higher (due to changes). The second part of Study 2 focused on this specific aspect of Environmental Enrichment Hypothesis. According to the

effect of critical timespans it was assumed that Openness's influence on activities during leisure time is relevant in the time after job loss (as example for a critical time span).

The second part of Study 2 used the same data as the first part (two occasion of Openness and reading each). But to prove this special assumption a subsample long-term data of PIAAC panel was used. Concretely, the sample included just these participants, which had a job at first time point but not at the second one. Thus, all people share the experience of job loss between the both occasions. This selection strongly decreases the sample size. So, less the 200 persons remain in the special sample. To test the effect of Openness for that specific situation (unemployment), a model was used representing the development in activities (reading books) and adding an influence of Openness on the change in this activity.

Results showed a high stability of reading in that time after job loss. This means this activity did not change. But there was an intraindividual change indicated by the change variable for reading activities included in model. However, Openness had no effect on this change. Different explanations were discussed addressing the high stability of reading and the missing support for an effect of Openness. It was concluded that further research is needed to support the assumption of the OFCI model. This research should use activities associated with unambiguous changes after job loss.

General Discussion

Motivation of the current work was to find out more about mechanism that explains the positive influence of Openness on development of cognitive abilities in adult age. The current model about the mechanism was based on the Environmental Enrichment Hypothesis of the OFCI model (e.g. Ziegler et al., 2012). This hypothesis assumes that more open people would seek for more new situations. By mastering these new situations, Gf would be used and grow by that way. As result of using Gf, Gc would also be fostered. The current work expanded that idea described in Environmental Enrichment Hypothesis. Thus, it is assumed, that the effect of Openness leading to more learning situations could be explained by manifestation of Openness in the specific selection of a job and activities during leisure time. Concretely, the current work proposes that more open people would more likely choose a job or leisure time activities, which are associated with more reading or calculating activities. By reading and calculating the people would have to deal with new information and problems. Mastering such a situation would foster Gf. As a result of solving a new problem by using Gf, Gc would grow (Investment Theory by Cattell, 1987). As the Environmental Enrichment Hypothesis this extended assumption should be valid for adult ages.

By testing the extended Environmental Enrichment Hypothesis, the current work wants to support the OFCI model in three ways: First, the work wants to support the idea that the effect of Openness on cognitive abilities (Environmental Enrichment Hypothesis) is valid for all adults. Second, the explanation given by the authors of OFCI model is added to the model

formulation and tested. Thus, it has to be shown that Openness's influence on cognitive development can be explained by Openness's manifestation in reading and calculating activities. Third, the work wants to show reading as important activity fostering cognitive development.

The Role of Openness in Cognitive Development: Generalization of Environmental Enrichment Hypothesis of the OFCI model

The Environmental Enrichment Hypothesis of the OFCI model (e.g. Ziegler, 2012) assumes that Openness positively influences the cognitive development in adulthood. Openness is seen as the personality trait associated with a tendency towards new and challenging experiences. To master these situations Gf is used. As a result of using Gf for processing new information, Gc is build to solve similar situations at a later timepoint. However, Openness is assumed to positively influence cognitive development by creating an enriched environment.

In early and later adulthood it would not be difficult to find such unknown situation (Ziegler, 2012, 2015). These timespans are characterized by a lot of changes. For young adult, these changes could be the entry into job life, becoming a family, or moving out of your parents' house. Also for older adults it is assumed that there are a lot of changes, e.g. retirement, death of partner. Early and late adulthood, are called critical lifespans, because of being characterized by these effectful changes. Influences can be seen in changes in personality. For these ages the effect of Openness could be shown in previous studies: Thus, Ziegler could show an influence of Openness on cognitive development for young adults (Ziegler, 2012) and older adults (Ziegler, 2015).

However, the OFCI model assumes that the positive effect of Openness and cognitive development exists for all adult ages, but is more effective in critical timespans. The basis idea is that more open people would themselves create a more challenging environment, even if the life does not bring these unknown situations by typically changes in life (e.g. first job). The current work proposes an extended Environmental Enrichment Hypothesis. This hypothesis assumes that adults of all ages would select their activities at work and during leisure time depending to their level of Openness. Thus, more open people would read and calculate more at work and during leisure time.

The hypothesis of environmental enrichment by activities is the general idea behind an environmental enrichment effect for all adult ages and was tested in the presented studies (see above). Therefore, a special sample was used which is representative for all adults in Germany. In Study 1, the proposed structural relationship of the core constructs (Openness, Gf, and Gc) could be supported. Results of the second study support the idea of the long-term influence of the environmental enrichment. Together with other studies (Baker & Bichsel, 2006; Wettstein et al., 2017; Ziegler et al., 2015; Ziegler et al., 2012) that have shown postulated association of Openness and cognitive development, the main idea of Environmental Enrichment Hypothesis could be supported.

But the current study wants not only to support generalization of the effect in that for all ages. The idea behind the positive effect of Openness on cognitive development is tested. This idea is about an effect not depend to the age of the people. The selection of activities at work and especially during leisure time is proposed to depend not on special ages and by that way not on

typically changes for these ages (e.g. first job or retirement). So, also this perspective supports the generalization of the effect for adult ages, beyond critical timespans.

The Role of Openness as Drive behind Activities at Work and during Leisure Time: The Extension of the Environmental Enrichment Hypothesis

The Environmental Enrichment Hypothesis of the OFCI model proposes a positive influence of Openness on cognitive development. The explanation is about a connection of both constructs by new situations. Thus, Openness would be a tendency to new situations, which could serve as learning opportunity. In such learning situation Gf would be used for processing the new information. As result of mastering the situation, Gc is built. Thus, learning situation would foster Gf and Gc. The likelihood for learning situations would be higher for more open people.

The current work extends the Environmental Enrichment Hypothesis of the OFCI model by giving more precise picture of a learning situation. Thus, it is assumed that Openness as the tendency to seek and engage in novel situations would manifest in specific activities at work and during leisure time. So, more open people would select a job or activities during leisure time, which are associated with novel situations, e.g. more reading and calculating activities This novel situation would be a learning situation fostering cognitive development. Thus, the extended Environmental Enrichment Hypothesis assumes that Openness manifest in specific activities at work and during leisure time, which can be seen as learning situation fostering Gf and Gc. This concrete assumption was not tested yet, but in the two studies of the current work.

First study of the current work focused the interplay of Openness, Gf, Gc, and activities in a cross-sectional design. It could be shown that the positive

influence of Openness on Gf is mediated by activities at work and during leisure time. In the second study Openness and activities (in that case only reading books) were focused in a longitudinal design. It could be shown that Openness influences the reading activity longitudinally. Thus, Openness predicts reading at later timepoint, controlled for the level of reading at a prior timepoint. However, both studies together make a bigger picture of longitudinal effect of Openness on Gf mediated by activities at work and during leisure time. So, the interplay of the variables is in accordance with the assumptions of the Environmental Enrichment Hypothesis extended by activities.

The Role of Reading as Opportunity for Environmental Enrichment

Main focus of the current work is to support the idea of Environmental Enrichment Hypothesis extended by activities. Thus, the positive influence of Openness on cognitive abilities is explained by the fact that more open people read und calculate more at work and during their leisure time and by this way fostering their Gf as well as Gc. Thereby, reading and calculating activities are seen as examples for possible activities. Thus, also other activities are possible. However, the Environmental Enrichment Hypothesis assumes that the effect of Openness on cognitive abilities is due to a tendency toward learning opportunities. Thus, the main characteristics of a possible activity should be the opportunity to learn something new.

In both studies of the current work reading books was used as example for a mediating activities. However, reading should be driven by Openness and result in a positive effect on cognitive development. The first study, showed that interplay for some activities including reading books. Furthermore, the second

study could show developmental effect of Openness on reading books. Both studies were made to show an effect of environmental enrichment by activities at work and during leisure time. However, reading books as concrete example was part of both studies. The current work could not only support the effect in general, but the specific example for such an activity working as environmental enrichment.

Implications and Future Directions

This work supports the Environmental Enrichment Hypotheses. This central assumption of the OFCI model (e.g. Ziegler, 2012) focusses on the positive effect of Openness on cognitive development. The current work extends these findings by further details about the effect itself and the mechanisms behind it. More precisely, the positive influence of Openness on cognitive abilities occurs through activities at work and during leisure time. Furthermore it could be shown that the influence is general and not depended on specific adult ages (young and older adults; see Ziegler et al., 2015; Ziegler et al., 2012).

Openness as Investment Trait and a Little More

The extended Environmental Enrichment Hypothesis proposes that people with a higher level of Openness show more engagement in intellectual activities, e.g. reading and calculating. This idea can also be found in research about investment traits (e.g. Von Stumm & Ackerman, 2013). The investment traits include a group of personality traits that are described by an association with cognitive development. The positive effect of investment traits is explained by the engagement in intellectual activities. This means that people with higher scores invest more time in typical intellectual activities, which in turn enhance intellectual abilities. Openness is one of these investment traits. Thus, this work supports not only the OFCI model, but also the basic assumption of investment traits. Concretely, the assumption about the positive effect on cognitive development by engaging in intellectual activities is addressed here. By extending the Environmental Enrichment Hypothesis to mediation through

engagement, the OFCI model and the theory about investment traits are connected. From this larger picture new questions arise: Is the specific meditation on engagement (e.g. reading and calculation activities) valid for further, possibly all investment traits or exclusively for Openness? It seems unlikely that this path is exclusive for Openness. Typical Intellectual engagement (TIE) is a central trait of the investment traits and reading is part of this construct (Goff & Ackerman, 1992; Wilhelm, Schulze, Schmiedek, & Süß, 2003).

This is in accordance with the fact that TIE and Openness are highly correlated constructs (Von Stumm & Ackerman, 2013). According to Ackerman, TIE "refers to the degree to which individuals prefer to engage in intellectually demanding leisure tasks, such as reading, and attending cultural activities such as concerts, lectures, and theater" (Ackerman, 2000, p. 73). This sounds very similar to what was shown for the Environmental Enrichment Hypothesis extended by activities at work and during leisure time. Openness manifests in these activities, which can serve new information developing cognitive abilities. Reading was shown to be such an activity behind environmental enrichment, but also other activities are possible (e.g. visiting concerts, see Ziegler, 2012). That means that the environmental enrichment by activities at work and during leisure time and the construct Typical Intellectual Engagement overlap strongly (Von Stumm, Hell, & Chamorro-Premuzic, 2011).

A possible relation between both constructs could be that TIE is a kind of ritualized manifestation of Openness. This idea is based on the influence of Openness on a situation being percept as intellectually demanding (Ziegler et

al., 2018). An example for this relation is that during listening to someone a person might recognize an unknown word. As a result a behavior associated with Openness is activated (Tett & Burnett, 2003). This could be a behavior to figure out the meaning of this unknown word, like reading in a dictionary. Because the person is getting new information the situation is solved (now the word is known) and the feeling of success arises. By repetition of similar situations (Wrzus & Roberts, 2017), such positive feelings would foster the general tendency towards new situation as well as the tendency to the specific use of reading as a solving strategy. Similar situations but without reading as option, only Openness (and maybe another specific behavioral tendency) is fostered. The other way around is possible as well. Different situations could activate another personality trait, but reading as an option to solve the situation is activated as well (e.g. a situation where someone has to read but does not want to, conscientiousness is activated). So both constructs are connected by environmental enrichment. This idea is in line with research about the relation between Openness and TIE, showing that both constructs strongly overlap. But they are still different constructs. An example is the relation to conscientiousness: TIEs correlates with conscientiousness while Openness does not (Mussel, 2010; Von Stumm, Hell, et al., 2011).

The facts that constructs similar to Openness (e.g. TIE), intercorrelate in a different way with other personality traits (e.g. conscientiousness) and performance variables (e.g. intelligence or academic performance, see Von Stumm, Hell et al., 2011), point to a lack of research in this area. The processes behind investment traits are still widely unknown and by that way possible beneficial and detrimental effects to environmental enrichment (e.g. influence

of conscientiousness). Environmental enrichment by activities at work and during leisure time is only one possible effect but can serve as an inspiration for further research in this area.

Openness and Intelligence from Different Perspectives

The OFCI model and associated research proposes a positive interplay of Openness and cognitive abilities from three related perspectives: (A) from the perspective of associated brain functions (DeYoung et al., 2012), (B) from a situational perspective (Ziegler et al., 2018), and (C) from a developmental perspective (Ziegler et al., 2012). Every perspective has its advantages.

From the perspective of brain functions the different aspects of Openness (Intellect and the aspect Openness) can be differed, because they are associated with different brain functions. The aspect Openness seems to be more relevant for perception processes, and Intellect seems to be associated with processes within the working memory. Despite these different associations with brain functions, both constructs seem to interact in a complex way to produce different kinds of performance. Here, the aspect Openness seems to be more important for creative performance, whereas Intellect is more important for Gf. But creative performance also depends on Gf. However, there is a paradoxical picture of influenced processes and associated outcomes (e.g. creative performance, Gf). Further research in this area is needed to clarify the interplay of all these constructs. The current work is one step in this direction.

In comparison to research on associated brain functions and constructs related to developmental interplay, research on the situational perspective of the interplay between Openness and cognitive abilities has just started. Ziegler and

colleagues (2018) created a basic model for the Environmental Enrichment Hypothesis on a situational level. It is assumed that Openness is activated by the perception of specific situational characteristics. Thereby, mastering such an intellectual situation would depend on the engagement driven by Openness (and interest) but also on the level of recent cognitive abilities. Finally, the feeling related to the result of effort (e.g. feeling of success) is associated with situational characteristics influencing the complex trait Openness. Further research in this area could draw a clearer picture of brain functions associated with specific variables in this model (e.g. Openness and perception of situations). Furthermore, it is possible to test beneficial and obstructive influences of these constructs. However, such effects may influence single aspects of a situation, but the model also proposes that a repetition of situations is the basis for change in traits like Openness and intelligence. These traits are stable over single situations, but a sum of similar situations could bring a change. However, research in this area also depends on the clarification of the function of constructs in their interplay beyond single situations. Thus, research from a developmental perspective is needed as the basis for further situational research.

The current work is based on the developmental perspective of the interplay of Openness and cognitive abilities. Important models according to the developmental interplay of relevant constructs were summarized in the introduction, such as the PPIK model (e.g. Ackerman, 1996), investment traits, the intellect framework and the OFCI model. All these frameworks have a common goal. They want to clarify the function of specific traits within the positive influence on cognitive abilities in a developmental perspective. The current work was focused on the Environmental Enrichment Hypothesis of the

OFCI model, extended by activities at work and during leisure time. The hypothesis proposes that Openness enriches a person's environment with learning situations fostering cognitive development. As mentioned in the prior section this influence is only one possible influence, but there seems to be more effects of traits on cognitive development.

However, the current work draws a picture of Openness as a personality trait creating an environment, which can positively influence the cognitive development. This influence is shown to be through activities at work and during leisure time. The idea that such activities positively influence the cognitive development is not new. The effect is known in other research as cognitive enrichment. This prior research states that the effect of such activities is positive but also confined, in the way that the effect helps people to get to the best possible performance, but not above a certain level. Furthermore, research about cognitive enrichment can be extended by the fact that personality traits like Openness are the drive behind peoples 'engagement activities fostering cognitive development. Thus, further research is necessary to test both effects (environmental enrichment and cognitive enrichment) for shared similarity beyond the activities and resulting cognitive development.

However, the OFCI model already includes an effect that could be associated with a limitation of the influence of Openness on cognitive abilities. That is the Environmental Success Hypothesis. This hypothesis describes a positive developmental influence on Openness associated with the mastering of new situations. That means by having no success the positive feedback would stay out. The likelihood of having success depends on the recent level of

cognitive abilities (Ziegler, 2012). The effects of Environmental Enrichment Hypothesis and Environmental Success Hypothesis create a bigger picture of mutual regulation processes: cognitive abilities foster Openness and Openness creates an environment matching with that level of cognitive abilities. The current work finds results indicating an effect of environmental success, but to clarify such a question, more research is needed on a situational level.

Practical Implication: Read More Books!

As a last implication I want to give a practical one. However, the focus of this work is not to prove what we should all do to become smarter and stay smarter. Rather, it was shown that Openness positively influences the development of cognitive abilities and further that the effect of Openness is through activities open people engaging in (e.g. reading). Such activities could help people to unfold their maximum of possible performance. An increase in Openness is a good possibility to support successful cognitive development. But Openness is a personality trait and correspondingly very stable. It is not an absolute stability, but still the position of a single person within a rank order in a reference group does not really change. As mentioned before, aspects that could be responsible for that stability of Openness (e.g. regulation by environmental success) need further research.

On advantage of the current work is that it supports reading books as an activity at work and during leisure time positively influencing cognitive development. Even if the idea is proposed that these activities occur due to higher levels of Openness, the bigger picture of all effects show (Tett & Burnett, 2003; Ziegler et al., 2018) a complex regulation mechanism, resulting in a balanced system of different internal needs and external demands. Many of these effects are still not known, but one was already supported: the effect of interest. According to research of Ziegler and colleagues, interest is a drive working parallel to Openness. Interest is not a general effect as Openness but is associated with specific content (e.g. social, artistic). However, interests have a positive

influence within the effect of environmental enrichment (Ziegler et al., 2018). Furthermore in context of work, a match of interest and content of the specific work is seen as associated with higher work performance (Holland, 1959, 1996). In association to the central constructs in cognitive development (Gf and Gc), investigative, artistic, and realistic interests are shown as crucial (Ackerman & Beier, 2003; Ackerman & Heggestad, 1997; Kaufman & McLean, 1998; Von Stumm & Ackerman, 2013). According to the question what practical implication the current work could give, book reading is recommended as a fostering activity. Thereby, a specific book should be chosen by the personal interest to foster an effect on cognitive development.

To sum up this discussion, the current work showed that environmental enrichment is an effect related to Openness. Environmental enrichment describes an effect that could be shared by other investment traits, but not the whole spectrum of possible influences. Environmental enrichment is the process of creating a fostering environment through activities at work and during leisure time, which fosters cognitive development. However, effects of other personality traits (e.g. conscientiousness) and particular investment traits need to be focused on in further research. Thereby, research should also look at the effect of environmental success as an important idea of a complex balancing mechanism of cognitive abilities and the influence of personality on the environment. Reading is an important activity within the environmental enrichment mechanism. Reading about things that match a person's interests is recommended to foster personal cognitive development.

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Eidesstattliche Erklärung

Hiermit erkläre ich an Eides statt,

- dass ich die vorliegende Arbeit selbstständig und ohne unerlaubte Hilfe verfasst habe,
- dass diese Dissertation zum ersten Mal eingereicht wird,
- dass ich mich nicht an der anderwärts um den Doktorgrad beworben habe und keinen Doktorgrad in dem Promotionsfach besitze,
- dass keine Zusammenarbeit mit gewerblichen PromotionsbearbeiterInnen stattgefunden hat, und
- dass ich die zugrundeliegende Promotionsordnung vom 5. März 2015 kenne

_____

Stefanie Trapp